VOL. 5 NO. 2 JUNE, 1918

PROCEEDINGS 38TH YEAR

JUL 2 1918
UNIV. OF
Engineering Library

JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

PUBLISHED QUARTERLY BY THE

AMERICAN WATER WORKS ASSOCIATION

AT 2419-21 GREENMOUNT AVE., BALTIMORE, MD.

SECRETARY'S OFFICE, 47 STATE ST., TROY, N. Y.

Entered as second class matter April 10, 1914, at the Post Office at Baltimore, Md., under the act of August 24, 1912

COPYRIGHT, 1918, BY THE AMERICAN WATER WORKS ASSOCIATION

R. D. WOOD & CO.

PHILADELPHIA, PA.

MANUFACTURERS

OF

MATHEWS FIRE HYDRANTS

Standard and High Pressure

CAST IRON PIPE

Bell and Spigot—Plain Ends—Flanged—High Pressure
Fittings of every description

VALVES

Gate—Check—Foot—Indicator

PUMPS

Centrifugal Pumps—Hydraulic Pumps—Pumping Machinery

GAS WORKS MATERIAL

JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

VOL. 5 JUNE, 1918 No. 2

CONTENTS

The Catskill Water Supply System. By J. Waldo Smith 91
The Water Works at Camp Grant. By Charles B. Burdick 100
Progress Report of the Committee on Sanitary Drinking Fountains 110
Centrifugal Pumps. By E. C. York 115
Methods of Determining and Plotting Meter Capacities and Some Results. By Fred B. Nelson 120
Water Purification Problems. By B. M. Mohler 132
American Water Works Laboratories. By Jack J. Hinman, Jr. 133
Recovering a Pump Lost in a Deep Well. By W. A. Judd 142
Prices and Depreciation of Cast Iron Pipe. By Burt B. Hodgman 145
Some Features in Artesian Well Construction in Mankato. By H. F. Blomquist 163
The Problems of a Small Water Works Plant from the Manager's Standpoint. By T. C. Gordon 165
Advantages of a Local Section of the American Water Works Association. By F. W. Cappelen 167
Notes on the Presumptive Test for B. Coli. By Max Levine 168
Labor Saving Machinery. By J. A. Jensen 172
Metalium. By Homer V. Knouse 174
New Design of Screen Chamber. By John H. Lance 181
Removal of Iron, Manganese and Carbon Dioxide from Water 185
Society Affairs 190

JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

The Association is not responsible, as a body, for the facts and opinions advanced in any of the papers or discussions published in its proceedings.

VOL. 5 JUNE, 1918 No 2

THE CATSKILL WATER SUPPLY SYSTEM[1]

By J. Waldo Smith

Organization. At the time of the inauguration of the McClellan administration, the fact that the consumption of water by the city of New York was rapidly approaching the limits of the existing supply had been pretty well demonstrated by several investigations conducted by the department of water supply, gas and electricity, by John R. Freeman's report to the comptroller in 1900, and by the Burr-Hering-Freeman commission in 1903. Mayor McClellan, with characteristic energy and thoroughness, reviewed all these reports and satisfied himself that it was necessary for the city to secure at once an additional supply of water, and, although other municipal improvements were put forward as necessary and advisable, he chose that of water supply as being most vital to the city's interest and the one which most demanded prompt attention. In the beginning of the second year of his first administration he secured the necessary legislation to make it practicable to proceed at once to determine the best sources from which to obtain an additional water supply and for its construction after the plans were approved.

It had been the uniform custom of the city of New York, when any great improvement was to be carried out, to put it in the hands of a special commission vested with broader powers than those possessed by any of the coördinated departments of the city government, in order that such special work might be more effectively and expeditiously carried out. This precedent was followed, and a board of

[1] Read before the New York Section on October 18, 1917.

water supply, composed of three commissioners, was selected by Mayor McClellan, on the recommendations of certain civic organizations. The statute contained a stipulation that the commissioners could be removed only on account of incompetence or misconduct, proved by hearing after due notice upon stated charges. This provision was designed to insure continuance in office during good behavior and to prevent the change of commissioners with each new city administration. The plan has worked admirably. No commissioner has been removed throughout the progress of the work to date, and only two have resigned, one to retire from active work and one to fill an important state office.

The board appointed the chief engineer. All other appointments in the engineering bureau, as well as dismissals and promotions, have been made by the board in accordance with the chief engineer's recommendations. In no case has a commissioner sought to control or influence these recommendations. This may seem somewhat remarkable in a city which has been so much maligned as the city of New York in past years. This maligning is often done by its own citizens, who, in lecturing throughout the country from time to time, attempt to appeal to the popular prejudice that all public employees are incompetent or dishonest, and make the most astounding statements, with no knowledge of the facts and without even trying to learn them. The author doubts if any other public improvement—national, state or municipal—throughout the country can show a better record.

Preparation and approval of general plan. The chief engineer's appointment took place on August 1, 1905, and a small corps of engineers, about 27, were available by September 1.

The first work in hand was the preparation of a general plan covering an additional supply of water by gravity to the five boroughs of the city. It did not seem advisable to make additional extended investigations as to sources of water supply. Previous investigations and legislative action had pretty well fixed those which might be developed. By utilizing all the information available, and by close application and great energy on the part of the small working force, which was increased to 55 during the month of September, within the space of about five working weeks reconnaisance surveys had been made and a complete plan, including estimates, was prepared, excepting the major part of its delivery system within the city. This plan was approved by the board of water supply and submitted

on October 9 to the board of estimate and apportionment for approval. With the exception of some minor modifications this is the plan which has been carried out. The original estimate, exclusive of the part of the delivery system which was omitted, was $162,000,000. A year or two later studies for the delivery system were completed, and the additional cost estimated at $15,000,000, making the estimate for the entire work $177,000,000. This estimate was made with practically no subsurface investigation. Although there have been many changes in legislation, such as the 8-hour law, the law providing for the establishment of the aqueduct police, and the provision for the payment of indirect and business damages, all of which tended to add to the cost, in an amount estimated to be from $8,000,000 to $20,000,000, it is believed that the work will be completed within the original estimate. As the matter stands today, the actual disbursements and liabilities are $139,000,000. A liberal estimate for completing the unfinished work is $37,000,000, making a total of $176,000,000, or $1,000,000 less than the original estimate, without allowing any credit for the additional expense imposed by legislation.

The approval of the board of estimate and apportionment was secured within the minimum statutory limit of two weeks, and it then remained to obtain the approval of the state water supply commission, which was created simultaneously with the board of water supply and was given general supervision over the sources of water supply to be chosen. Application to the commission was made promptly, and hearings were held, extending over six months. After securing additional legislation to cover indirect and business damage and police protection the general plan was approved by the state water supply commission, in June, 1906, thus making it possible to proceed with the surveys and investigations necessary for the preparation of the construction contracts.

Prosecution of work under contract. The construction contracts were put forward rapidly, so that the first contract, for 11 miles of aqueduct in the vicinity of Peekskill, was awarded in March, 1907. The largest contract on the entire work, that for the main dams of the Ashokan reservoir, of a value of over $12,500,000, was awarded in August of the same year. Other contracts were prepared as rapidly as possible, so that all those involving a large volume of work outside the city were operative before the end of 1909. The main contracts for the delivery of water within the city were awarded in 1911.

Delivery of water to the city. The first water was actually delivered to the city on December 27, 1915, and thereafter a small quantity was delivered throughout that winter and intermittently during 1916. The general delivery of water to all boroughs began in January, 1917. The first delivery of water was made at least a year sooner than was anticipated, and it would have been possible at any time since April, 1913, to deliver water for an emergency period through the Croton aqueduct, had necessity arisen.

Working force and expenditures. The maximum force in the engineering bureau at any time was 1348, in 1911. The maximum labor force employed on all contracts at one time was 16,229 in the same year. The largest expenditure in any month was $3,900,000, in June, 1911, and for one year was $25,900,000 in 1911.

Completion of contracts. The following facts are pertinent. All the construction work, about $100,000,000 in value, has been accomplished by the original contractors or their legal representatives, without the intervention of the city or a call on a surety company to advance money. The author wishes it could be said that the contractor had made a fair profit in every case, but this is probably too much to expect. Difficulties were encountered, due in some cases to low bids, and in other cases due to failure of the contractor to adopt the best methods for doing the work. That the latter was the fact in some cases was very plainly brought out by the operation of contiguous contracts, for the same class of work under approximately the same working conditions, where one contractor, at a lower price, has made a handsome profit, while another, at a higher price, broke even or made a small profit, and in some cases operated at a large loss.

None of the contracts contained provisions for doing work other than that directly provided for in the items of the contract. While it is believed that there should be in contracts provisions for doing extra and additional work, with suitable safeguards, in order to afford greater elasticity, such provisions were debarred by the representatives of the law department. In spite of this handicap, the work was accomplished without the embarrassment of having to suspend operations on a single contract in order to have work done which had not been anticipated or provided for.

Completion within estimated cost. The amounts paid under all the construction contracts, aggregating $100,000,000 in value, averaged approximately 5 per cent less than the amount bid. This is not

claimed to be a saving, as some have tried to make it appear. Nevertheless, it has had a good effect on the public mind because the dear public is prone to consider that any additional expense over the amount bid on a contract is due to incompetence in the preparation or to collusion on the part of those executing it and that such excess is always an increase in the cost. As a matter of fact, we know that the actual cost is neither increased nor decreased.

Importance of preliminary investigations. Believing that very thorough investigations were absolutely essential as a preliminary to the preparation of contracts for construction work and that failure or serious complications are quite frequently due to lack of such preparation special effort was made to have the preliminary inevestigations as thorough and exhaustive as was consistent with economy. Investigations in connection with the location of the dams and of the aqueduct line required the making of 14 miles in depth of wash borings, 31 miles in depth of core borings, the excavating of numerous test shafts and trenches and the making of 3400 miles of preliminary surveys. All this information was exhaustively studied and analyzed. This thoroughness was all the more essential for the preparation of contracts in which there could be no provision for doing other work than that specifically provided for under the items of the contract. The contract and specifications, in the course of their preparation, went through the hands of the most skilled workers in headquarters, and they were also particularly examined by the engineers in the field, who would execute the work, before being put into permanent shape. It was due to this carefulness, and this alone, that it was possible to conduct the whole work, a large part of which was prosecuted under the surface of the ground, without meeting any unforeseen difficulties which had not been anticipated and provided for. Many an undertaking has been wrecked, or seriously hampered, by untimely haste in beginning work, before thorough preparation was made, in response to the popular demand for the "dirt to fly." Due to the great business activity during the early years of the work, or to some kind Providence, this misfortune was averted. The contracts and specifications, as prepared, were intended to give the fullest information to bidders. No attempt was made to conceal or belittle any of the difficulties which were anticipated; instead, an effort was made to emphasize them, and the men in field were instructed to call the attention of prospective bidders to any physical condition

which would affect the execution of the work or the prices to be bid.

Payment items. The contracts contained specific payment items for much work usually included in general expense, and an effort was made to provide a payment item for all work which could be reasonably segregated and measured. The work included in each item and the method of measurement and payment for same were carefully set forth, with the intent of preparing contracts and specifications, which, so far as possible, would eliminate controversies and differences of opinion. This could be successfully done to only a limited degree, for it is impossible to write in this language so that it will be interpreted in the same way by all readers.

Construction of dams in sections, with drainage systems. The building of the dams in sections, with transverse joints about 80 feet apart, has prevented cracking through the body of the masonry on account of contraction, and has incidentally served as an aid to construction, both as to safety and convenience. The masonry between the borders of the drainage system is so impervious that it is uncertain whether this drainage system would be effective or not. As a matter of fact, practically no water runs into it except at the expansion joints. From this experience the author is inclined to eliminate the main drainage system and retain the building in sections.

Construction of steel-pipe siphons. In constructing the steel-pipe siphons, the plates were first pickled to remove all the mill scale before fabrication at the shop. In the field the pipe was laid on concrete saddles carefully set to grade, and after a siphon was completed and full pressure was applied the pipe was completely surrounded with concrete of sufficient thickness to prevent deformation when empty. The pipe was then unwatered and 2 inches of cement mortar placed on the inside. This was accomplished by setting up forms inside the pipe and placing a 1:1 grout around the forms. This resulted in an exceedingly smooth lining, which, up to date, has shown no tendency toward loosening from the pipe. It is believed that this pipe is more completely preserved than by any bitumen coatings previously applied. It certainly provides a much smoother inner surface.

Pressure tunnels. Pressure tunnels are not new. As long ago as the construction of the Croton aqueduct, a pressure tunnel was built from a point north of Jerome Park reservoir to the reservoir

at 135th Street, including the crossing under the Harlem River in the neighborhood of Highbridge. The only marked difference between that pressure tunnel and those constructed on the Catskill work is that the maximum pressure in the case of the Croton was only a little over that due to 100 feet head and that for most of the distance the hydraulic grade was below the level of the ground, or slightly above it, whereas for the Catskill tunnels the average unbalanced head is equal to at least 250 feet and at some points is as high as 425 feet. This enormously increased pressure was the most difficult feature to deal with and one which received exceedingly careful consideration in preparing the design. The result was the establishment of an arbitrary rule that at no point should the sound rock cover for any appreciable distance be less than 150 feet. As a matter of fact, the sound rock cover is materially more than this at practically every point.

The Hudson River crossing. The Hudson River crossing is the most striking example of the pressure tunnel form of construction. The problem of designing suitable apparatus to unwater this tunnel was more difficult than the designing of the tunnel itself. The accepted design consists of two centrifugal pumps of about 5,000,000 gallons combined capacity, each capable of lifting water under a head of about 700 feet and, when arranged in tandem, to raise the water 1100 feet or more, of course with a reduced capacity. This tunnel has been unwatered two or three times with this apparatus with entire success. It is of a portable nature and can be removed to the other pressure tunnels and used in the drainage shafts in a similar way.

Leakage from tunnels. It was anticipated that the leakage from the tunnels in the rock, lined only with concrete, under such high pressures, would be material. It was originally believed that, in the cases of the Rondout and Wallkill Valleys, which are each about 4½ miles across, if each tunnel did not leak more than 1 million gallons daily they would be very satisfactory, probably not greater than from a steel pipe of equal capacity laid in the ground. As a matter of fact, the initial leakage on the first filling was greater, but quickly decreased to a moderate amount and has continued to decrease since, so that the present leakage in all tunnels 36 miles in length, with an interior surface area of 8,700,000 square feet and an average effective outward pressure of 250 feet, is 567 gallons per minute. The leakage of 18 miles is from recent measurements, the

leakage of the city tunnel is estimated from previous measurements. This amount of leakage could be carried through a $1\frac{3}{4}$-inch nozzle under that head.

The city tunnel. A pressure tunnel provided the only reasonable and practicable solution of the delivery of water within the city. The thoroughfares running north and south were already crowded with public utility structures, in the way of gas and electric conduits, subways, etc. Besides this, the inconvenience to the public during construction would have been excessive if it had been necessary to bring this large quantity of water through the city in pipes under the surface. After careful investigations, it was decided to build a pressure tunnel through the backbone of The Bronx and Manhattan Island, crossing the Harlem River, and then the East River to Brooklyn. This tunnel is over 18 miles long, the longest tunnel in the world. This type of construction was also 50 per cent cheaper than delivery by pipes. Contrary to expectation, there have been indications of water at the surface at only two points, at 23d Street and Broadway and at 57th Street and 6th Avenue, and only a very small quantity at each of these points. In cold weather it is most noticeable and at the present time has practically disappeared. One curious matter in connection with the leakage from the tunnels has been observed for at least four years, which is that the leakage varies inversely with the temperature, being at its maximum about March of each year and its minimum the latter part of September, and that both the maximum and the minimum decrease each year. The opportunities for measuring this leakage have been exceedingly favorable, and has been accomplished by measuring in the end shafts of the pressure tunnels at such times as the water is shut off in the aqueduct, this being equivalent to a tank measurement.

When any great project is carried to successful completion, the public likes to believe that one individual is responsible for the success of it, but there is nothing in this view and we all know that success comes, if it comes at all, through the inspiration, confidence and strength, that come with united effort and effective coöperation, on the part of all connected with it. It is certain that any success which may have been achieved on this work is due more to the quality and character of the individuals in the organization than to their leaders. What has contributed most to the effective conduct of the work has been the almost uniform belief and confidence in

one another, the high sense of loyalty and the willingness to sacrifice personal ambition and preferment for the good of the work. All held the good of the work above every other consideration. The policy has been to work with the contractors—not against them; to help and not to hinder. Any other policy means an economic waste. None have been more loyal or more conscientious, or have contributed more to the success of the work.

The author does not claim that this organization has had a monopoly of loyalty, but he does believe that the ties that bind have been a little stronger and more flexible, the sacrifice of personal ambition has been greater and that the loyalty has been more spontaneous and effective. It is certain that association for years with an organization of this character is worth more than any honor or personal preferment which might possibly come to any one, due to his connection with it and its successful completion.

Acknowledgment should be made of the cordial coöperation which has been given by the successive city administrations and by all the men connected with the coördinated departments of the city government with whom we have come in contact. All have been willing to grant the privilege of a hearing at all times. The author desires particularly to acknowledge the very complete coöperation of the chief engineers of the department of water supply, gas and electricity, Mr. de Varona, Colonel Smith and Mr. Brush, and also of the members of their organizations. They have gone out of their way, in season and out of season, to assist in every possible manner. It would have been wrong to have had any other relations between these two departments which are so closely concerned with the water supply of the city, one having to do the planning and construction of the additional supply, which, on completion, devolved on the other department for maintenance and operation.

THE WATER WORKS AT CAMP GRANT[1]

By Charles B. Burdick

Camp Grant, located upon the Rock and Kishwaukee River 5 miles south of Rockford, Ill., is typical of sixteen divisional cantonments constructed to house the National Army. It furnishes accommodations for 36,000 men as originally planned. As completed it provides housing for 42,000 men and 10,000 animals. Each building is supplied with water. Each barrack is accompanied by a lavatory in a separate building also supplied with hot and cold water and equipped with water closets, urinals, wash sinks and shower baths. The buildings total 1520 and cover an area measuring about 3 miles north and south by $1\frac{1}{2}$ miles east and west.

Water supply requirements. The requirements for water supply demanded first, absolute healthfulness, second, adequate fire protection for a rather congested city of wooden buildings, and third, a speed of design and construction that has probably never been equaled for a water supply of the size required.

The instructions to the constructing quartermaster required that water should be provided to the amount of not less than 55 gallons per day per man, or about 2,000,000 gallons per day for the 36,000 men originally proposed for Camp Grant. Instructions further provided that the plant should be capable of delivering water to the distribution system at 2.85 times the above rate, or approximately 5.7 million gallons per day. This was obviously intended to refer to rates for very short periods.

It was required that the water should be furnished under a pressure not less than 60 pounds and not more than 85 pounds unless greater pressures were necessary to distribute the water.

Available supply sources. Northern Illinois is a well watered country and surface supplies are almost everywhere available, but on account of the abundance of ground water, they are seldom used for domestic purposes. A surface water supply at Camp Grant would have been particularly undesirable, even if filtered, on

[1] Read before the Illinois Section on November 15, 1917.

account of heavy sewage pollution in the two streams which border the camp. An investigation was made to determine the practicability of purchasing a supply of water from the city of Rockford, but the quantity available was not sufficient.

There are two sources of ground water everywhere available in the northern one-third of the state, namely, the St. Peter sandstone and the Potsdam sandstone. In most of the river valleys it is also possible to develop water sufficient for a municipal supply from the glacial and alluvial sands and gravels.

The St. Peter sandstone is from 150 to 250 feet in thickness, and in Rockford wells to penetrate it completely would be from 400 to 500 feet deep. A part of the Rockford municipal supply is obtained from this source.

The Potsdam sandstone is much thicker, reaching a thickness of upward of 1000 feet at Rockford. It contains numerous veins of water. The top of the Potsdam sandstone is reached locally at a depth of about 500 feet, and wells about 1500 feet in depth usually are required to fully develop this formation.

The blanket of glacial drift overlying bed-rock varies in thickness in the vicinity of Rockford up to 200 to 300 feet in those places in the valley of the Rock River that were eroded by the ancient stream. In these places the St. Peter sandstone lies immediately below the glacial drift. The glacial drift and river alluvium overlying bed-rock largely consist of sand and gravel and are filled with water below the ground-water plane of the region, which is approximately the level of the streams. Water can be withdrawn from the drift in large quantities where the water-bearing stratum has sufficient depth and porosity. In the city of Rockford the drift in many places is thin and uncertain in character to such extent that no large supplies have been drawn from it, the general practice being to enter the underlying sandstone for all large and moderately large water supplies, such as the municipal supply and private supplies for various manufacturing institutions in the city.

All underground waters of the region are excellent from the hygienic standpoint. All three of the available underground waters are, however, moderately hard.

The time available would not permit of an underground reconnaissance by test borings to determine the most practicable place adjacent to the camp to develop a water supply. Knowing that the sandstone would furnish the required water if it could not be de-

veloped in the drift, it was promptly decided to procure well drilling outfits capable of penetrating the St. Peter sandstone, or going even deeper if advisable. It was further decided to select a locality as favorable as possible so far as surface indications went; to keep an accurate log of the drift materials encountered in constructing the wells, and to utilize a supply in the drift should favorable materials be disclosed in the construction of the permanent wells, otherwise to continue the wells into the St. Peter's sandstone.

It was estimated that with good luck, a St. Peter's well would require about six weeks in drilling. It was further estimated that from six to eight wells would be required to supply the camp. Under these circumstances it would not be practicable to supply the camp by September 1 without employing a number of well drilling rigs. Accordingly, arrangements were made for the rental of four deep-well drilling outfits which were placed at work as rapidly as they could be secured, transported and erected.

The wells. The condition of the pipe market was such that material for private work was practically unobtainable, and pipe for use in well casings was obtainable by the government only with great difficulty and delay. It was early recognized, therefore, that well casings must be ordered at once, capable of completing all necessary wells under the most unfavorable circumstances of the underlying formations that would be likely to be developed in construction.

Under the provision of the general contract, the well drilling outfits were rented by the general contractor under a special contract, the general contractor providing all labor and operating and maintaining the drilling outfits. On account of heavy developments in the oil regions, considerable time was required for the delivery of well-drilling repair parts, and to forestall materials required for maintenance, a supply of drills, cables and other equipment was ordered that would probable be worn out in case it was necessary to drill into the sandstone. One well strainer was provided in order that the first well could be tested should favorable materials be disclosed in the overlying drift.

On June 29, an arrangement was closed with F. M. Gray, Jr., to furnish such well drilling rigs as would be required up to a total of five rigs. The first rig was delivered about the middle of July, and closely followed by two others, and on August 1, three rigs were in operation at depths of 71, 62 and 79 feet respectively.

The first well, after passing through the surface alluvial soil, had entered sand and gravel which continued to a depth of about 90 feet; then the drill passed into clay to 115 feet; then into quicksand and clay to a depth of 135 feet, and then into good coarse water-bearing sand to a depth of 156 feet below the surface. At this point the conditions were deemed sufficiently favorable to insert a strainer and test the well. This was immediately done, and on August 13 the well was tested, producing 311 gallons per minute with a drawdown of 13 feet. It was then decided to develop the drift water supply in the remainder of the wells should equally favorable conditions be found. Favorable materials being encountered three wells were completed during the month of August and two additional wells in September. The last of the six wells was completed October 25.

TABLE 1

Specific capacity of individual wells

WELL NUMBER	PUMPAGE RATE IN GALLONS PER MINUTE	DRAW-DOWN BELOW STATIC WATER LEVEL, FEET	SPECIFIC CAPACITY, GALLONS PER MINUTE PER FOOT OF DRAW-DOWN
1	311	13.0	23.
3	225	10.0	22.5
4	299	8.1	36.8
5	263	10.75	25.
6	286	6.42	44.5
7			18.0

All wells are equipped with Johnston strainers having a No. 40 slot. Four strainers are 10 inches in diameter and 16 feet long. Two strainers are 20 feet long and 8 and 10 inches in diameter respectively.

As is the case with all wells in granular materials such as sand and gravel, the practicable rate of pumpage is directly proportional to the depression of the water surface in the well incident to pumping.

All the 10-inch wells are equipped with 5-inch air lift pumps and pipes having an economical capacity each of 500 gallons per minute. The specific capacities of the wells vary somewhat, but the variation in capacity is taken up in different amounts of drawdowns in the several wells. The original tests of the several wells are given in table 1.

As above stated, the capacity of each well, as developed, is lim-

ited by the air lift installation, and it would be possible, if need be hereafter, to increase the capacity of the well system by installing larger air lift pumps. With the present compressor outfit the plant has shown its ability to produce water at the rates given in table 2.

The lift under which the wells operate varies with the amount of water produced, and varies somewhat in the different wells. Measured from the water surface in the well when operating up to the discharge head, the lift varies from 40 to 50 feet, and averages 42 feet when five wells are in operation furnishing the water supply for the present camp, amounting to about 2,300,000 gallons per day.

The wells were spaced at intervals of 300 feet on centers in order that there may be a minimum of interference, particularly having in

TABLE 2

Capacity o well groups

NUMBER OF COMPRESSORS IN SERVICE	NUMBER OF WELLS IN SERVICE	WATER PRODUCED GALLONS PER MINUTE	GALLONS PER MINUTE PER WELL
1	3	1,376	459
1	4	1,525	381
1	6	2,160	360
2	5	2,470	494
3	5	2,656	531
2	6	2,740	457
3	6	3,300	550

mind the possibility that it might be necessary to go to the Potsdam sandstone for a water supply. The percentage of interference, that is to say, the delivery per foot of draw-down of the group of wells as compared to the sum of the capacities of single wells added together, is approximately 77 with five wells in service. This percentage varies slightly, depending upon the individual wells in service.

Elastic development required. As no time was available to sink test wells and pump them, it was necessary to assume the underground conditions as accurately as possible and to adopt pumping devises that would be workable under any conditions likely to be disclosed in the construction of the works.

Accordingly, it was decided to adopt double pumping, and in view of the possibility that St. Peter's wells would be used, it was

deemed advisable to install an air lift pumping system of sufficient capacity to lift the water, at the demanded rates and height, 100 feet if necessary. At the same time the design was worked out so that it would be reasonably well adapted for pumping a smaller quantity of water against as high a head as 150 feet, or a greater quantity of water against a head of 50 feet or even less.

This general plan of development seemed economical under the circumstances because the probable temporary nature of the supply made it desirable, as a general principle, to pump a few wells to a considerable depth rather than a large number of wells to a less depth. Furthermore, there is probably no means for pumping well water that is more reliable in its operation and that is less likely to derangement than the air lift pump.

For the above reasons the air lift was adopted for Camp Grant. It was decided to install three air compressor units, each capable of pumping 1000 gallons per minute against a total head of 100 feet. This would allow a development of 2000 gallons per minute with one machine in reserve. In the development of the water supply from the drift under a less head, the pump capacities of the compressors are proportionately increased, as indicated by the figures of yield previously shown.

A canvass of the power situation disclosed a very good central generating station in Rockford privately owned, with the practicability of purchasing power on a sliding scale rate. The necessity for a quickly installed plant and the probability of very reliable service from the Rockford installation led to the very early decision to utilize electric power in the water works pumping operations.

As a reserve for use in case the electric power should be temporarily unavailable, an oil engine was installed which could furnish the camp with water for a short time. This pumping unit proved to be very valuable, for it enabled the plant to begin pumping operations about a weak earlier than would have been possible with electric power.

Pumping equipment. Electrically driven centrifugal pumps were adopted for the high lift equipment on account of the rapidity with which they could be furnished, transported and installed. Stock apparatus was used for part of the equipment. The low installation cost per unit of capacity also made this equipment highly desirable in a pumping plant of a more or less temporary nature.

The drilling of the wells, the construction of the concrete reser-

voir and the foundations for the pumping station equipment were begun simultaneously about the middle of July.

The first pumping unit, the oil engine and its pump, was set upon its foundations about August 20, and began pumping on August 25. At this time the building foundation wall only had been completed, and to prevent damage from the weather, the engine flywheel and the belt were covered with a shed constructed of boards and building paper which protected the apparatus until the building was under roof. The air compressors were installed during the last week in August and the first compressor began pumping September 1. The first electric driven pump went into service August 31.

When pumping operations began, the filling around the reservoir was not entirely completed, and the plant started with about 5 feet of water in the reservoir. This was gradually increased as the embankment was completed.

Storage of water. A storage reservoir was adopted intermediate between the low lift and high lift pumps, in order that the well system might be operated as nearly at a uniform rate as possible, thus providing a surplus of water so that the high lift pumps might follow the fluctuating rates of water consumption. This reservoir also serves as a reserve which can be drawn upon for fighting fires. A circular concrete reservoir 16 feet deep containing 300,000 gallons was built for this intermediate storage.

While the average water consumption of the camp should not much exceed 2,000,000 gallons per day, the rate of use at certain hours will probably greatly exceed the ordinary uses of a city, for the reason that all inhabitants of the camp will be subject to the same rules as to the time of arising in the morning, meal hours and going to bed at night. For this reason the use of water, particularly at meal times, is very great, reaching as high a rate as 6,000,000 gallons in twenty-four hours.

In order that these reasonable fluctuations in demand may be taken care of without an excessive installation of machinery, pipes and water supply, it was thought to be desirable to install an elevated tank which, during the peak of the water demand, can feed the system from the center, thus more than doubling the available capacity of pumping machinery and distribution pipes.

Accordingly, a contract was entered into about July 10 with the Chicago Bridge and Iron Works for furnishing and erecting an elevated tank of 300,000 gallons capacity, 140 feet high, from plates in

stock. This company agreed to complete its work by September 15, and it was, therefore, expected that it would be necessary to operate the water supply by direct pressure for about two weeks. The tank was delivered on the ground and erection started on July 28, and by the use of a double force and work during practically all of the daylight hours, the erection was completed on August 20, five days in advance of the completion of the pipe line which permitted the delivery of the water to the camp.

Distribution system. It was early appreciated that the water distribution system, involving 16 miles of mains and 20 miles of service pipes, would require a very prompt delivery of materials and concentrated work to permit supplying water to the troops on September 1. For numerous reasons it was decided at Washington that so far as possible the water pipes should be made of wood.

The wood pipe originally reserved for Camp Grant was rejected and the order cancelled. A rush order for wood pipe was then placed with Pacific Coast mills, and to expedite construction about half the order for 10-inch pipe was placed with cast iron pipe factories and shipped from Scottdale, Pa. Later, to facilitate construction, an additional order was placed for about 3700 feet of 10-inch cast iron pipe shipped from Ohio, and still later, authorization was granted to purchase 10,000 feet of 8-inch cast iron pipe to be shipped from Ohio stock to hasten the completion of the pipe lines.

The valves and hydrants reserved for Camp Grant were provided with the standard bell ends common in water works practice. The wooden pipe reserved for this camp was connected by means of a tenon and a double hub coupling, the tenon being driven into the hub of the coupling. Where special fittings or valves were connected to wooden pipes, or where wooden pipes were connected to iron pipes, a special form of fittings was necessitated. The manufacturer with whom the original pipe order was placed, recommended cast iron fittings with machined hubs of such size as to fit the tenon on the wood pipes, and fittings of this kind were specially made for the work.

Upon the delivery of the wooden pipe from the Pacific Coast it was found that the tenons were too small to make a tight joint in the machined hubs purchased to use with the wood pipe originally ordered. This difficulty was overcome by sawing off the spigots upon certain of the pipe and cutting a new spigot on the ground

after unwinding a few strands of the banding. Later in the work it was found that a passable joint could be made with a standard water pipe fitting without machining, and a large number of such joints were used.

The lack of water pipe during July and the early part of August made it possible to concentrate the work of the trenching machines on sewer pipe laying. Early in August, however, when the sewers were nearing completion, it became necessary to utilize a part of the trenching machines on water pipe, and accordingly, several miles of water pipe ditches were opened, and stood open until pipe arrived.

The first water pipe reached Camp Grant August 14. Considerable difficulty had arisen in holding experienced pipe layers on account of the delayed delivery of the pipe, but as rapidly as possible, the gangs were reorganized. On August 25, the pipe line between the pumping station and the elevated tank, about 6000 feet in length, was completed, and the water was turned in. Since this date the camp has been continuously supplied.

On August 31, pipe lines with attached hydrants had been extended through the northwest and southwest wings of the camp, and moderately good fire protection was afforded to every part of the camp where buildings were completed. On this date, 6 miles of water mains were in place, and 5 miles of water service pipes. By September 12, about 70 per cent of the pipe laying had been done, and shortly after the middle of the month there only remained to lay the pipe supplying the stables, not then authorized, and the additions to the camp occasioned by the remount station and the training battalion. This work was completed during the very unseasonable month of October.

Difficulties. It must not be assumed that the work was carried through without difficulties or disappointments. This was far from the facts. Although everyone tried to anticipate difficulties and provide for them in advance, there were few days during the first six weeks when something wholly unexpected and detrimental to progress did not arise. Space will not permit recording them here, but they were real difficulties at the time, and that some of them did not defeat the purpose of the work is due to the superintendents and foremen, who displayed great resourcefulness in emergencies.

Early in the work, before everyone's powers and duties were clearly understood, there was much in the way of chasing up blind

alleys and coming out again before the right path was found. The good nature displayed by everyone in these encounters was surprising. In fact, it was a feature of the work from first to last, that in case of error everyone searched for the remedy rather than a "goat" to place the blame upon, and it was this spirit among the men engaged that made this strenuous work a pleasure.

PROGRESS REPORT OF THE COMMITTEE ON SANITARY DRINKING FOUNTAINS[1]

In response to the active popular demand a large number of manufacturers are now offering for sale so-called sanitary drinking fountains. This means that a very wide variety of types of fountains is now available. In any town or city many different types will probably be found. In a recent investigation at the University of Minnesota out of 77 drinking fountains 15 different types were found. Two general classes of fountains are now on the market, the intermittent flow type and the continuous flow type. Each of these general classes may again be subdivided into two subclasses: those with suitable mouth guards and those without suitable mouth guards.

Most of the fountains now available seem to have been designed with reference to appearance rather than to the laws of sanitary science. Although many of the fountains are extremely neat and attractive in appearance, nevertheless with a little thought they will be found to provide small security against the transmission of contagious diseases. Some of the fundamental principles which most fountains violate are as follows:

First, the fountain should be so designed that the lips of the drinker may not touch the metal top of the bubbler. In spite of this self-evident fact, it was discovered last year in a canvass of the catalogs of 39 manufacturers that only 6 of them appreciated the importance of this detail, since only 6 of these 39 provided suitable mouth guards for all of their fountains.

In order to demonstrate the need of mouth guards, your committee employed an observer to inspect the use made of two fountains without mouth guards. One fountain was of the continuous flow type with a bubble $\frac{5}{8}$ inch in height. It was located in a public library. During the period of observation 59 persons drank from the fountain, 22 of whom were children, and 37 adults. Of the 22 children, 15 placed their lips upon the metal top of the bubbler in

[1] Read before the Iowa Section at its annual meeting, October 10–12, 1917, at Council Bluffs.

drinking, while 7 did not. Of the 37 adults, 28 placed their lips upon the metal top, while only 9 did not. One adult had an eruption upon the face, and one was apparently in bad general health.

The second fountain was of the intermittent flow type with a bubble ¾ inch in height. It was located at a street corner. During the period of the observation 43 persons drank. One was a small child that had to be held up in order to drink. This child placed its lips upon the metal top of the bubbler. Of the remaining 42 persons, 18 were children, and 24 adults. Ten of the 18 children placed their lips upon the metal top, while 8 did not. One of these children was apparently in bad general health. Nine of the 24 adults placed their lips upon the metal top, while 15 did not.

Such facts are conclusive evidence of the need of mouth guards. Any observer may easily obtain his own evidence of this need by watching the use made of fountains without mouth guards in his own town.

Second, no fountain should be so designed that the incoming bubble of water passes through a cup of contaminated water which cannot drain out. Many of the new drinking fountains in the State of Iowa are of this type. Actual experiment has found that when coloring matter is added to these cups, it is retained for long periods of time before the fresh bubble passing up through the cup of water has removed all of the stain. Of course the bacteria from the lips of the drinker may readily fall back with the escaping water into the cup and seriously contaminate it. Such a contamination would exist for a long period of time before all traces of it had disappeared.

Third, in the case of bubble fountains without mouth guards no effort seems to be exerted to maintain a height of bubble sufficient to permit easy drinking without resting the lips directly upon the metal top of the bubbler. This is usually the fault of the owner of the bubbler and not of the manufacturer. It may, however, be the fault of the manufacturer in case he has not provided a pressure regulator which is so designed that an ample height of bubble will be maintained for ordinary variations in pressure in the service pipe of the fountain. This is an especially important point in the case of school buildings where at recess times or between classes large numbers of fountains are in use at the same time. This lowers the pressure in the service pipes considerably and a well designed pressure regulator on each fountain becomes an absolute necessity.

Fourth, fountains should be so designed that the water which

has touched the lips of the drinker cannot be retained by the fountain long enough to endanger the next drinker. With the present vertical jet type of fountain, if it is designed upon the intermittent flow principle, when the flow is stopped after a drinker is through, the water in contact with the lips falls back upon the top of the bubbler. If the bubbler is then in the act of draining out, some of the contaminated water may be drawn within the bubbler itself. In any case, it runs over the surface of the bubbler, making it possible to deposit thereon disease germs or particles of mucous membrane. In the case of vertical jet fountains, designed upon the continuous flow principle, it would seem at first thought that no danger of this kind would exist. Of course such a fountain, if it had an undrained cup, might violate the second principle of design noted above and be a continual source of danger.

The following question, however, is not yet satisfactorily answered: Is a properly designed, continuous flow, vertical jet fountain dangerous, and if so, why? Experiments upon such a fountain, made in the laboratory of medical bacteriology at the University of Wisconsin in 1915 shows real danger. The bubbler tested was an ordinary continuous flow type, consisting of a perforated top which screwed into the center of a hollow metal bulb. The experimenters washed out their mouths with suspensions of B. prodigiosus, and then without touching the metal portions of the fountain, drank from a bubble 2 to 3 cm. in height. In one case the bacterium thus introduced was recovered after one hundred and thirty-five minutes. The average maximum length of time which the bubble retained the organisms was twenty-five minutes. The reason why these organisms were retained for so long a time has not been demonstrated. The theory has been propounded that these organisms danced upon the column of water much as a ball dances upon the top of a garden fountain. It seems to your committee that more experimental evidence is necessary in order to show that the continuous flow, vertical jet type of fountain, if properly designed, is so dangerous as this one set of experiments seems to prove. Accordingly your committee would ask that it be continued another year in the hope that it may find the time to conduct a series of experiments along this line.

So far as your committee is aware only 4 manufacturers have as yet realized the dangers lurking in the vertical jet type of fountain. Within the past few weeks one of these manufacturers has placed

upon the market a new type of nozzle. This nozzle throws a jet at a slant and the nozzle itself is so protected that it cannot be contaminated. The nozzle is designed after the drawing by H. A. Whittaker, Director, Division of Sanitation, Minnesota State Board of Health, published in the Public Health Reports, vol. 32, no. 19, p. 695, May 11, 1917.

The laboratory investigations thus far have all shown the inherent danger of the vertical type of bubbler. The experiments at the University of Wisconsin on one occasion showed 43 out of 77 bubble fountains, or 55.8 per cent, to be contaminated with streptococci. On a second occasion 35 out of 50 fountains were found to be contaminated with streptococci, 70 per cent of the total. The immediate occasion for starting these investigations at the University of Wisconsin was an epidemic of streptococcus tonsilitis which occurred in the fall of 1914 in one of the women's dormitories. In seeking to find the source of the spread of this epidemic the drinking fountains were examined and found to be heavily contaminated with streptococci. Similar investigations at the University of Minnesota found that of the 77 drinking fountains in use 80 per cent were infected with streptococci.

A bibliography is appended to this report, giving all the references to papers on sanitary drinking fountains with which your committee is acquainted.

Conclusions. First, all drinking fountains should have suitable mouth guards. Second, sanitary fountains of the intermittent flow type with the vertical jet are unqualifiedly condemned. Third, sanitary drinking fountains of the continuous type, with a vertical jet, even when properly designed, would seem to be possible factors in the spread of contagious disease, if the Wisconsin laboratory experiments are confirmed by further tests. Fourth, the slanting jet type of fountain with the nozzle properly protected is perfectly safe, simple in design, and inexpensive to purchase. A design is already on the market which may be attached to any of the present type of drinking fountains. Fifth, your committee asks to be continued in order that it may make further investigations, particularly with reference to continuous flow bubblers of the vertical type.

Respectfully submitted,

J. H. DUNLAP, *Chairman,*
HENRY ALBERT,
JACK J. HINMAN, JR.

BIBLIOGRAPHY

S. C. KEITH, JR.: An Improved Bubbling Drinking Fountain. American Journal of Public Hygiene, 1910, vol. xx, p. 163.

JANE L. BERRY: Bubble Fountain Tests, Collected Studies from the Bureau of Laboratories, City of New York, 1914–15, vol. viii, p. 135.

PETTIBONE, BOGART AND CLARK: The Bacteriology of the Bubble Fountain. The Journal of Bacteriology, September, 1916, vol. i, no. 5, p. 471.

J. H. DUNLAP: The Sanitary Drinking Fountain. Journal of the American Water Works Association, March, 1917, vol. iv, no. 1, p. 65.

H. A. WHITTAKER: Drinking Fountains—An Investigation of Fountains at the University of Minnesota. Public Health Reports, May 11, 1917, vol. xxxii, no. 19, p. 691.

CENTRIFUGAL PUMPS[1]

By E. C. York

The trend of the times in power plant equipment shows plainly a movement from the reciprocating toward the rotary type of machine, whether turbine, motor, blower or pump. The centrifugal pump is one of the important developments in this evolution. Its low initial cost, small repair charges, durability, and high pumping elasticity, compel instant recognition. But if there is one machine which demands a full knowledge of its peculiar limitations, it is the centrifugal. A single pump used at constant speed for a wide range of capacity and lift is inefficient and unreliable, for the centrifugal pump gives its best results only when intelligently designed for each specific condition of operation, in accordance with the results of years of careful experimentation and consequent improvement. This evolution enables the manufacturer to guarantee better results than have hitherto been practicable, particularly as regards the multi-stage or high-lift pumps, which, as now made, are adaptable for many purposes not hitherto considered the field of centrifugal pumps. By reason of compactness, elasticity and high power, they afford a solution of pumping problems perplexing many engineers and their use makes it possible to materially reduce pumping costs.

The first centrifugal pumps had impellers with single radial wings, and these have developed into the more efficient enclosed or shrouded impellers. The combination of two or more separate centrifugal pumps in series, each discharging into the suction of the succeeding one, is not new, and very satisfactory results have been obtained for some time with this arrangement. It does away with the division sleeve between the first and second stage impellers, which is a source of a very large percentage of loss, for this sleeve becomes worn rather rapidly. There is no way to take up this leak except to remove the sleeve and replace it with a new one with new bush-

[1]Read before the Minnesota Section April 21, 1917.

ing, which at the present cost of bronze metal is a somewhat expensive job.

When purchasing a centrifugal pump there are five points of prime importance which every buyer should investigate most thoroughly:

1. Reliability of the pump in service.
2. Efficiency, including provisions for maintaining the original efficiency.
3. Life of the pump, or its ability to resist wear and corrosion, and the ease and cost of repairs when deterioration occurs.
4. Accessibility of all internal parts and ease with which inspection or repairs can be made without special tools.
5. Methods of manufacture, reliability of guarantees, accurate test and general service given by the pump manufacturer.

It is quite evident that several of these factors are in a measure dependent on others, and also that a pump to give the best possible results must combine all five of them. In the selection of hardly any other class of mechanical equipment do all these considerations need more careful attention on the part of the purchaser than in the case of pumps, for the reason that a machine handling water or other liquids must resist not only the usual mechanical wear but also the corrosive and erosive action of the liquid.

Reliability of operation and a constant and adequate supply of water are of great importance in any water supply system. It is therefore essential that the machine be one that will operate continuously without shut-downs or delays from mechanical troubles, and one that will not require constant and expert attention on the part of the operators. In the design, the question of reliability should be given first consideration, and each and every part should be so made that its operation is certain and dependable. The bearings should be large and carefully made, and the arrangement for lubrication should be given particular attention. Balance, both mechanical and hydraulic, should be adequately provided for in order to avoid the gradual deterioration always resulting where there is vibration. All parts of the machine should be made of such materials and of such strength that they are rugged and suitable for continuous operation for long periods.

The efficiency of a pump, or in fact of any machine, is of importance. The life of a pump is measured not only by its ability to resist wear and deterioration but also by the ease and convenience

with which it may be repaired and thus restored to its original efficiency. High efficiency maintained for a short time is of no particular value, as true economy is a matter not only of the initial efficiency, but also of the ability of the machine to maintain this efficiency, and of the ease, convenience and cost with which the owner can re-establish the efficiency after the machine has been in operation for such time as necessarily causes parts to become worn or damaged. The question of accessibility is thus coupled with that of efficiency, for the reason that the machine that is easily accessible is more likely to be inspected from time to time by the operator, so that its interior condition will become known.

The design, workmanship and materials employed in a pump should be such that the original efficiency will be maintained for the longest possible period. For this reason, the engineer should not recommend cast iron impellers, because such impellers are corroded rapidly and wear much faster than the bronze impeller, resulting in a marked decrease in efficiency. As the working member of the pump the impeller exercises the greatest influence upon the efficiency. It must be properly designed, with correct surfaces and smooth finish, and it must be of material which will withstand wear and maintain the original form and smoothness. The type used in centrifugal pumps should be the inclosed or shrouded impeller, in which the blades are located between side plates, forming inclosed passages.

The type of wearing ring is also of great help in maintaining the original efficiency. The greatest leakage occurring in a centrifugal pump is from the discharge chamber to the suction chamber, between the impeller and the casing. Leakage at this point is not ordinarily detected, even when excessive, and in many pumps, causes a considerable reduction in the pump capacity and efficiency. Ordinarily this joint is formed between cylindrical surfaces concentric with the shaft; the leakage path is therefore straight and presents little resistance to the flow, and the clearance space discharges as much water as would an ordinary plain orifice of the same area subjected to the same pressure difference. The engineer should realize the great practical advantages to be secured by reducing the leakage in centrifugal pumps as much as possible.

Very desirable results have been obtained by the labyrinth type of division rings, consisting of two removable rings, one attached to the pump casing and the other to the revolving impeller. Each

ring should be made to standard gages so that it can be replaced without fitting. The intermeshing grooves form a labyrinth, or tortuous passage, through which the water must pass in order to escape from the discharge to the suction chamber. The many bends in the path of the water create additional resistance to its passage, which, with the greater absolute length of the path, greatly reduces the leakage as compared with that with straight rings. The rings should be of bronze, the same material as the impeller.

Manufacturers have abandoned the use of diffusion vanes, as it was found that they deteriorate rapidly, which results in marked decrease in efficiency. They greatly complicate the interior of the pump, introduce a number of separate pieces and internal joints, rapidly become worn and eroded, particularly at the tips (which should be finely formed) and are ruined by solid bodies, such as stones, sticks or gravel, jamming between the tips of the blades and the pump impeller.

Efficient, reliable and accurate methods of manufacture by a builder of centrifugal pump equipment are of value to a purchaser in many ways. The essence of the matter is that high grade machines can be produced only by a shop using high grade methods, tool equipment, inspection and testing. Neglect of these vital matters may entail heavy expense and great annoyance later, which will far offset any possible saving in first cost. High grade workmanship and materials are not necessary for the successful initial mechanical operation of a centrifugal pump, but they are essential to long life and maintenance of efficiency and are thus of great importance in future years.

In 1910, the management of the Minneapolis water department decided to increase its pumping capacity. To this end, a thorough study was made of different types of pumps. The Minneapolis General Electric Company submitted a proposition to furnish electric power for an electrically driven pump on an "off the winter peak load basis," which included the months of November, December, January and February only, at a flat rate of $4 per 1,000,000 gallons pumped to the reservoir against a total head of 240 feet, with a combined motor and pump efficiency of 72 per cent.

Largely on account of this offer, the Water Department asked for bids on two 20,000,000 gallon two-stage electrically driven centrifugal pumping units, and also on one 20,000,000 gallon vertical triple expansion pumping engine. The bids received on the triple

expansion engine varied from $88,000 to $106,000. The Henry R. Worthington Company's bid of $28,665 was accepted for two 20,000,000 gallon electrically driven, two-stage pumps of the single casing type. The contract specified that each two pump was to be driven by a 1200 horse-power, 60-cycle, three-phase, 2200-volt, slip ring induction motor, with an efficiency on full load of at least 94 per cent. The rise in temperature of any part of the motor, after a full load run of twenty-four hours, should not be more than 40°C. The combined pump and motor efficiency was guaranteed at 75 per cent.

The Minneapolis General Electric Company signed a ten year contract to furnish power at the price mentioned. The two pumps were turned over to the city in April, 1912, and have been in constant service since, except, of course, for the necessary time for repairs. The pump at the Northeast Station has been running three years without a single shut-down for repairs and with only about 1 per cent reduction in efficiency in three years. The Camden Station pump, however, has had to be overhauled annually on account of sandy water, which causes a drop in efficiency of about 5 per cent a year. On this account it is very necessary to make provision for renewing or repairing the wearing or division rings.

It has been found practicable, when the ring or the impeller becomes worn enough to require renewing, to take the impeller out, face the surface in a lathe, and renew the ring in the pump casing to fit the turned down impeller. The old set is put away for future use, and when the impeller ring is worn enough so that it will not admit of further wear, it is faced for the last time, a resurfacing ring shrunk on to take the wear, the old set of casing rings bored to fit, and practically a new pump results. The tips of the impellers do not wear enough to affect the efficiency of the pump and the casing shows no material wear.

It is worth while to give the stuffing boxes some attention, especially where there is sand or grit. The difficulty has been overcome at Minneapolis by using filtered water to seal the glands.

The operation of the centrifugal pumps has shown a considerable saving over the triple expansion units in the items of labor and maintenance. This saving was estimated at the time of installation as possibly $10,000 a year; five years' experience has proved the saving even higher than originally estimated. It amounts practically to $1.50 per 1,000,000 gallons pumped to the reservoir, or about $15,000 per year, according to present rate of consumption.

METHODS OF DETERMINING AND PLOTTING METER CAPACITIES AND SOME RESULTS[1]

By Fred B. Nelson

The relative merits of meters may, in general, be shown by a comparison of their accuracy, sensitiveness, durability and capacity.

Accuracy is an important, in fact, an essential feature easily determined by test and the only one to which the average city gives serious consideration. Yet there is hardly a meter on the market that cannot meet the usual accuracy requirements, particularly the positive displacement type of meter in which accuracy, only, calls for little refinement of design beyond an accurate fit of the piston in its chamber. The feature of accuracy, therefore, gives very little as a basis of comparison of the different makes and types and creates little or no competition.

Sensitiveness or ability to register low flows is a feature which represents revenue in the registration of the small and often continuous flows which exist on nearly all classes of services, and is a feature in which the different makes and types differ more and upon which more competition could be established by city requirements.

Durability is not so susceptible of determination by test, but accelerated tests can be arranged which, in a short time, will more or less duplicate the service wear of years, and in justice to the efforts of meter companies in putting out durable products, greater recognition of this quality should in some way be made by more specific requirements.

Capacity, the fourth feature, is one which is susceptible of exact determination and one in which surprising differences are revealed between the different makes in the same size and often between the proportional capacities of the different sizes of the same make. It is a feature which has a direct bearing on the service pressures maintained and requires careful and intelligent designing if high capacity and relatively low loss of head are to be secured and the other essential features retained. Yet it is a feature that is quite generally

[1] Read before the Richmond Convention, May 10, 1917.

ignored and little incentive is held out to meter companies to perfect their products in this direction.

Recent meter testing of the department of water supply, gas and electricity of New York has been conducted with considerable attention to pressure loss and capacity, and the author feels that certain features of the methods used and the results obtained may be of interest.

The apparatus used consists essentially of the following: A mercury U-tube so connected by tubing with the inlet and outlet of the meter as to measure directly by the head of mercury the pressure loss between those points at the different rates of flow; tank scales for determining by weight the actual volume of water passed; a regulating valve for adjusting rates of flow; a quick-acting valve for starting and stopping the tests with a minimum of flow below the adjusted rate; and a stop watch for the accurate determination of the duration of flow.

The three elements, pressure loss, volume and time are thus obtained by single readings of apparatus having a very small percentage of error and the results are surprisingly consistent. The use of the mercury column in particular, by giving one direct and sensitive reading of the pressure difference, eliminates the mechanical inaccuracies of pressure gauges and many possible errors, due to the attempt to make simultaneous observations of two gauges, apply corrections and substract their readings. One pound per square inch of pressure corresponding to 0.455 inch of mercury deflection enables a very accurate direct reading of the pressure loss even on very low flow, which could hardly be taken with any degree of accuracy by subtracting the readings of two gauges.

Apparatus embodying these features was assembled and used by the author in making pressure-loss tests on all disc meters on the New York approved list and others submitted for approval in all sizes up to and including 2 inches.

In studies of pressure loss and capacity, the author feels that it may be of interest to call attention to some decided advantages in the use of logarithmic paper in plotting pressure-loss data and some features of pressure loss that are by that means illustrated. This paper is so ruled that equal distances, horizontally and vertically, correspond to the logarithms or powers of the numbers given on the ruling, so that in plotting any data in which one value varies as a fixed power of another, the graph or curve is that of the constant

ratio between the powers of the indicated values and is therefore a straight line.

The advantage in the use of this paper in plotting pressure loss is due to the fact that the pressure loss in meters varies very closely as the square of the discharge, so that if discharge values be plotted horizontally and corresponding pressure losses vertically, the points will define a straight line having a slope of one horizontal to two vertical. From this it follows that from but one correct determination of pressure loss at any given rate of flow, the pressure loss of all other rates of flow is at once determined by drawing a straight line through the one plotted point at this 2 to 1 angle (compare figs. 1 A and 1 B).

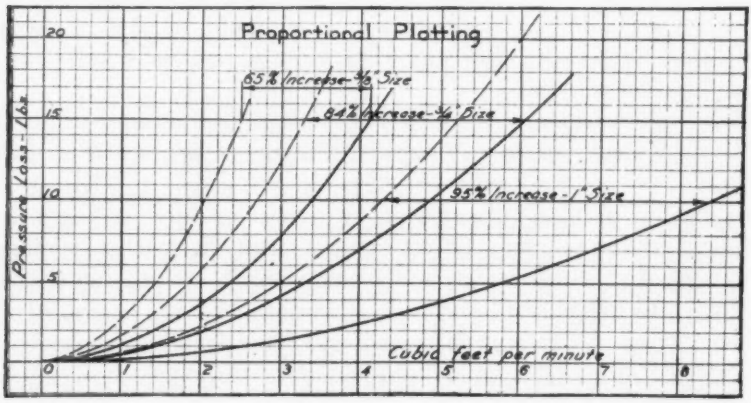


FIG. 1 A. IMPROVEMENT IN CAPACITY AND DECREASE OF PRESSURE LOSS EFFECTED BY REDESIGNING AND ENLARGING OF WATERWAYS WITHOUT CHANGE IN DISK SIZE; PROPORTIONAL PLOTTING

The slope of this line (2 to 1) represents the general law of pressure loss in disc meters and is therefore the same for all makes and all sizes, and the lines or graphs for individual meters of all makes and sizes are parallel (fig. 5). In the tests made, such a line has frequently been drawn from a determination at but one flow and afterward a different desired rate of flow has been adjusted to within 1 or 2 per cent by a turn of the regulating valve, bringing the mercury column to the pressure loss corresponding to the intersection of that line with the desired rate. The straight line also serves as a check against all errors of computation or reading where more than one determination of pressure loss is made, as the points must theoretically fall on

a straight line and any errors in results are at once conspicuous by the points plotting up off the line.

The disadvantage of the logarithmic plotting is that the values are not shown in their true proportions. Where, however, a proportional curve is needed it can easily be constructed in a few moments

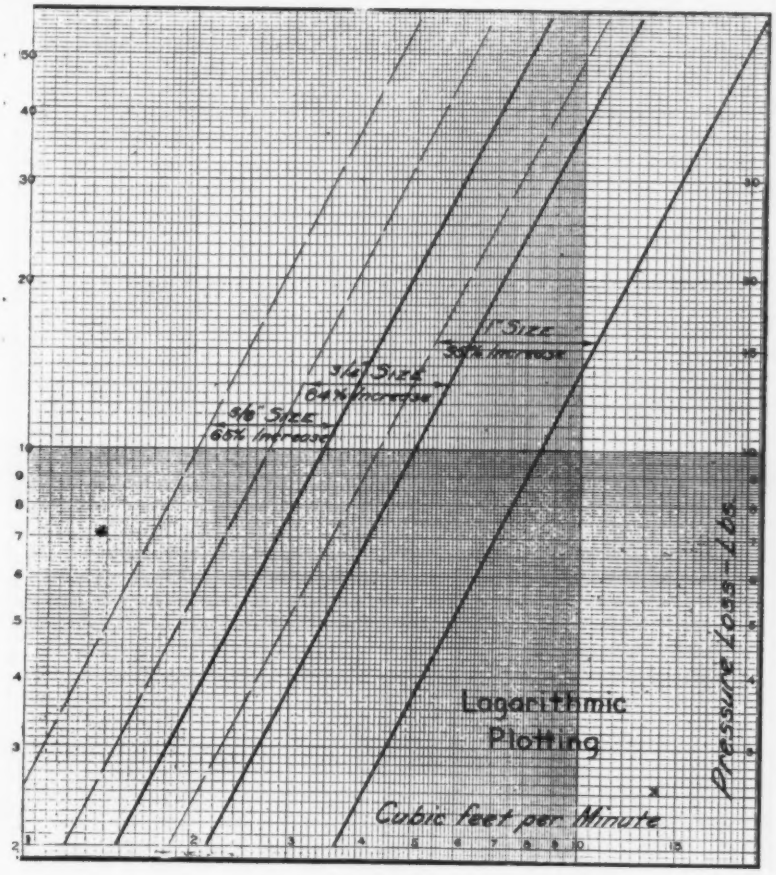


FIG. 1 B. SAME DATA AS FIG. 1 A—*Logarithmic Plotting.*

by plotting any desired number of points taken from the logarithmic line, with a consequent saving of a great amount of time otherwise required to obtain a sufficient number of test points in the ordinary way, including the essential low flows, to define the pressure loss curve well.

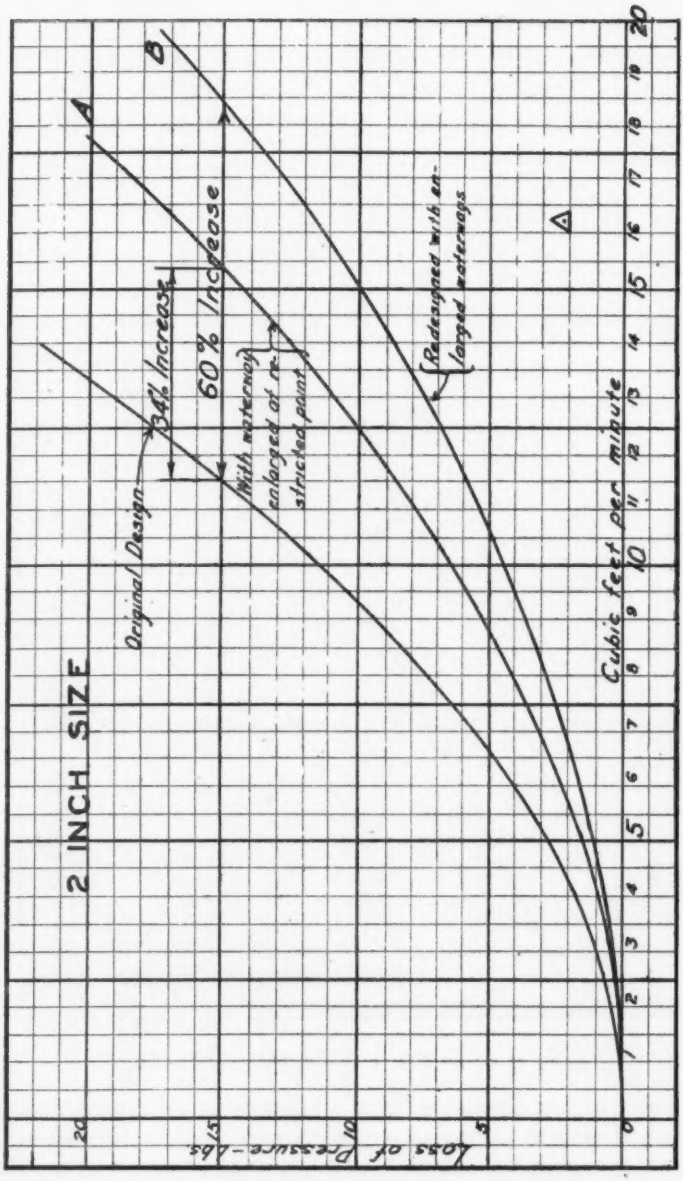


FIG. 2 A. IMPROVEMENT IN CAPACITY AND DECREASE OF PRESSURE LOSS EFFECTED BY IMPROVED CHANGES ORIGINAL METER, CURVE A, AND BY ENLARGED WATERWAYS EMBODIED IN IMPROVED COMMERCIAL TYPE, CURVE B

As a point of interest the slope of the straight line graph on logarithmic paper verifies the correctness of the formula that friction loss varies as the square of the flow. In the actual tests made this has been indicated to vary from the 1.94th power to the 2nd power of the rate of flow.

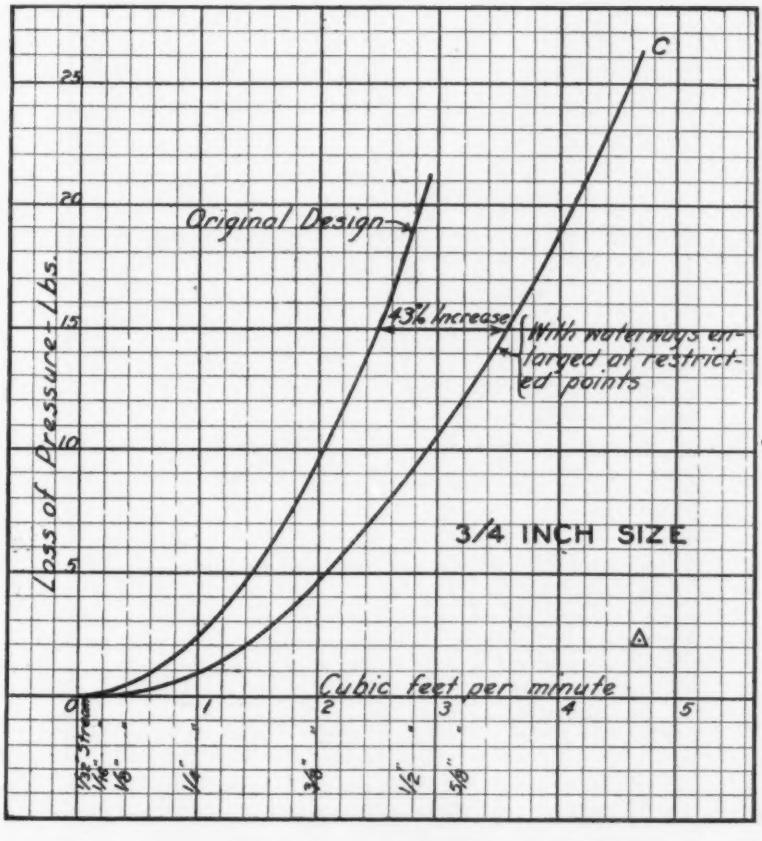


FIG. 2 B. IMPROVEMENT IN CAPACITY AND DECREASE OF PRESSURE LOSS EFFECTED BY ENLARGED WATERWAYS IN IMPROVED COMMERCIAL TYPE, CURVE C

Convenient use may be made of the logarithmic method of plotting in comparing the relative capacities of the different sizes in any one make (fig. 3—A, B, C and D. If diameters be plotted horizontally and corresponding areas of orifices vertically, the plotted points

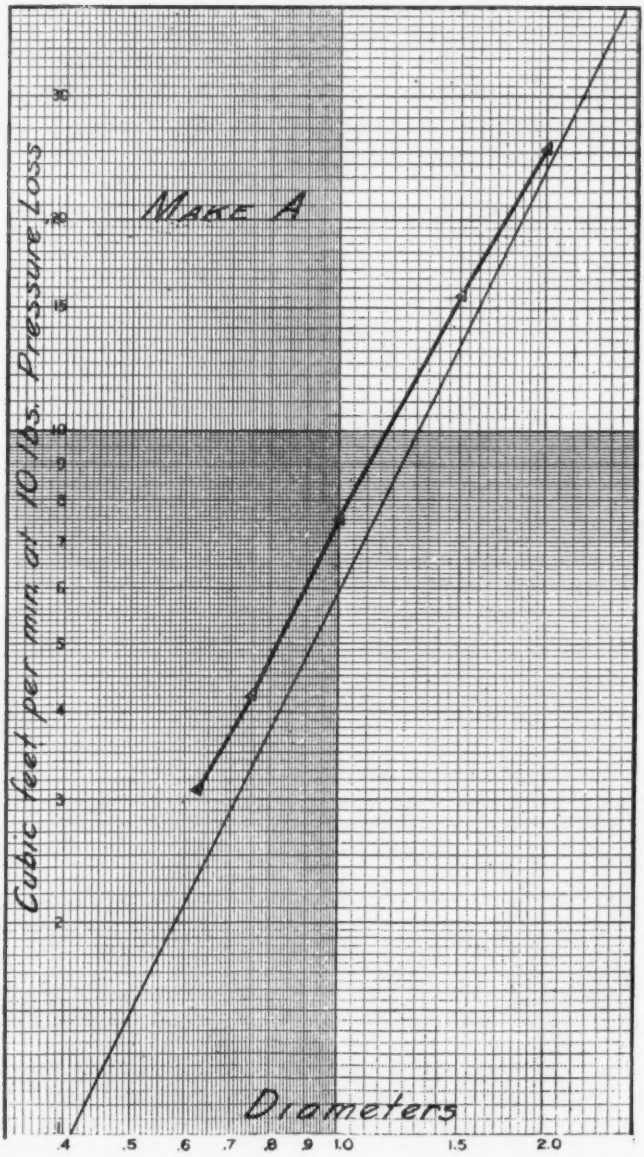


FIG. 3 A. PROPORTIONAL CAPACITIES OF METERS AT 10 POUNDS PRESSURE LOSS COMPARED WITH PROPORTIONAL DISCHARGE OF SIMILAR SIZED ORIFICES UNDER FIXED HEAD; WELL-PROPORTIONED METER OF HIGH CAPACITY

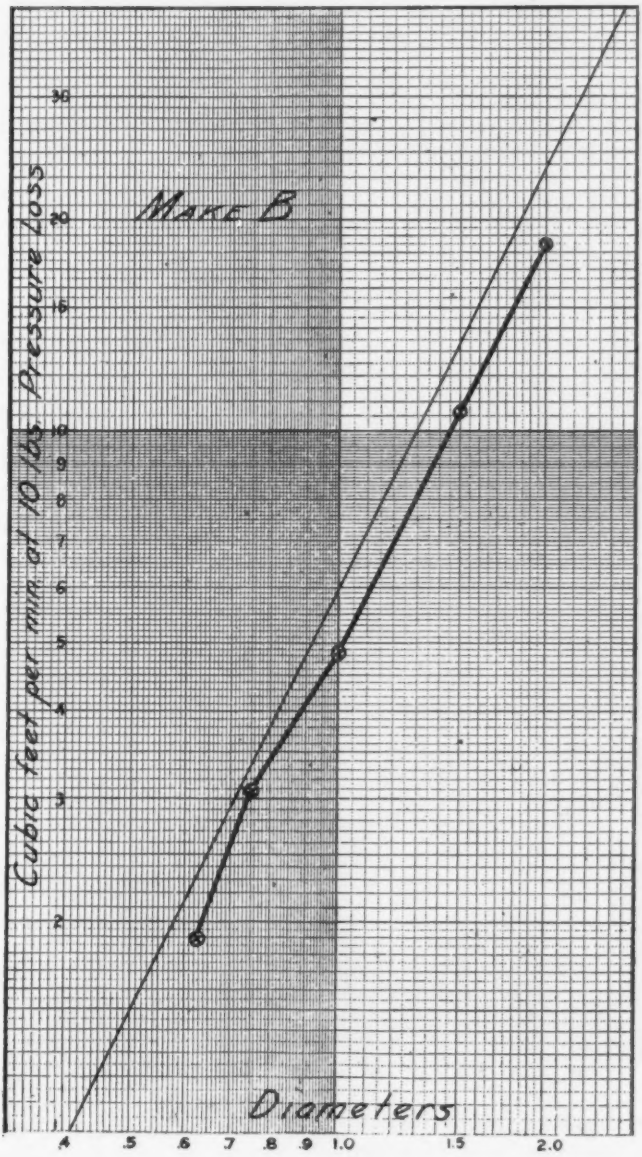


FIG. 3 B. PROPORTIONAL CAPACITIES OF METERS AT 10 POUNDS PRESSURE LOSS COMPARED WITH PROPORTIONAL DISCHARGE OF SIMILAR SIZED ORIFICES UNDER A FIXED HEAD; WELL PROPORTIONED METER OF LOW CAPACITY

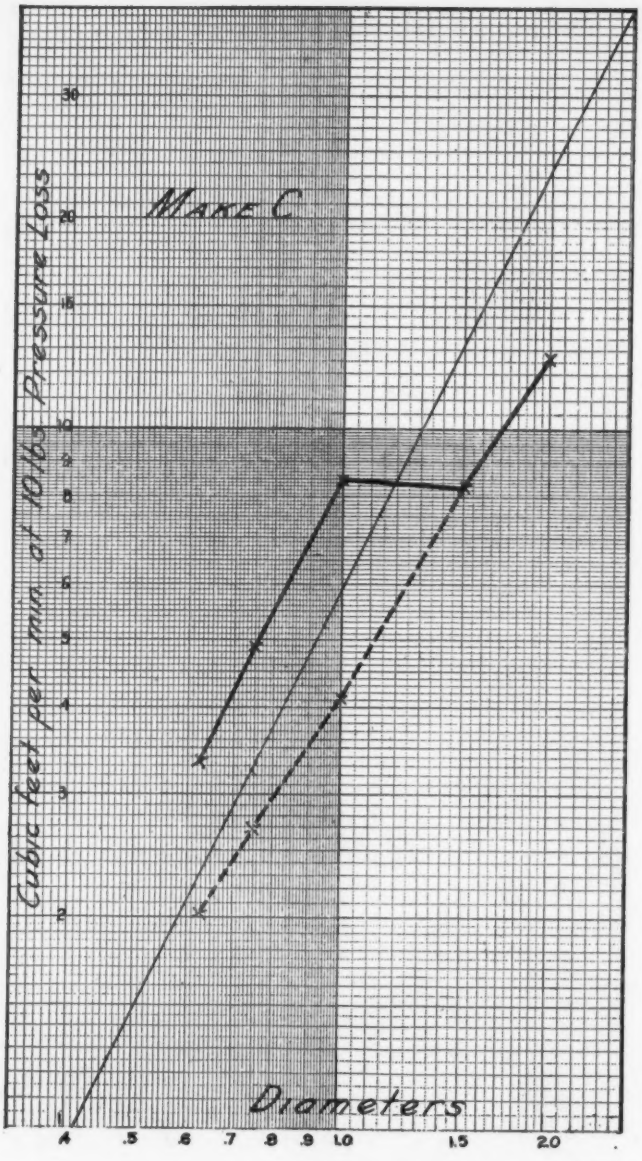


FIG. 3 C. PROPORTIONAL CAPACITIES OF METERS AT 10 POUNDS PRESSURE LOSS COMPARED WITH PROPORTIONAL DISCHARGE OF SIMILAR SIZED ORIFICES UNDER A FIXED HEAD

The full line shows the present proportional capacities of improved $\frac{1}{8}$, $\frac{3}{4}$ and 1 inch sizes as illustrated in Figure 1, and the dotted line shows the capacities of the original design.

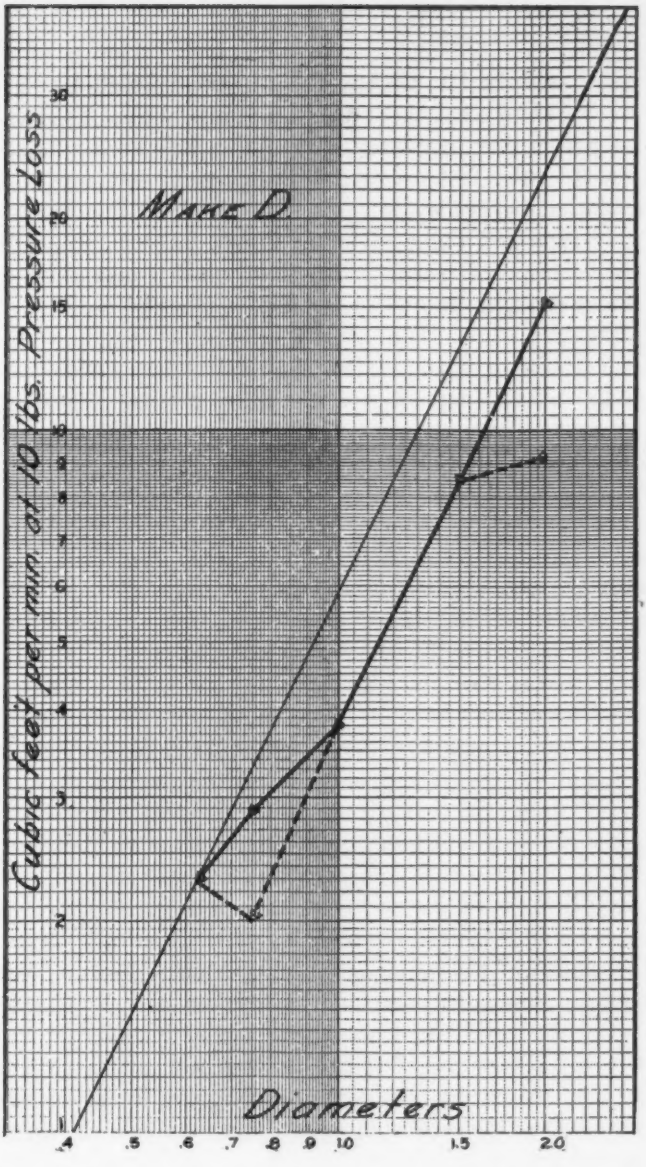


FIG. 3 D. PROPORTIONAL CAPACITIES OF METERS AT 10 POUNDS PRESSURE LOSS COMPARED WITH PROPORTIONAL DISCHARGE OF SIMILAR SIZED ORIFICES UNDER FIXED HEAD

Dotted lines show the variation from ideal proportions in the original designs which were rectified by the increases of capacity shown in Figures 2 A and 2 B.

will define a straight line with a slope of two vertical to one horizontal, the area and consequent discharge under a fixed head varying as the 2nd power of the diameter. Using the same horizontal scale of diameters, the cubic feet per minute discharge of each size of meter may be plotted vertically. If now it be assumed that the capacities of one type and make of meter should vary in proportion to orifices of corresponding sizes, then these plotted capacities should also define a straight line which should be parallel to that representing areas.

By such studies of capacities it is shown that a very wide variation exists in the relative capacities of the different sizes of some makes (fig. 3) as well as an extremely wide variation in the capacities of different makes in the same size (figs. 4 and 5).

There are a number of features of design which at once suggest themselves as affecting capacity more or less directly and in some cases these features seem to have been sadly neglected. In the tests made the capacity seems to be but slightly affected by size of disc and number of mutations, except, possibly, in cases where the total friction loss is small and the disc size and speed enter in as an appreciable part of the total loss. In most cases, the size and shape of the waterways have far more direct bearing on the capacity. In the construction of pumping machinery, great emphasis is placed on easy curves of waterways and very gradual changes of direction in the flow of water, particularly on suction lines where but little friction loss can be permitted. Some meters seem to have been designed with the same care and attention to these details, while in others very little attention seems to have been given. Frequently waterways are so restricted as to act as partially closed valves and often the course of the water is abruptly reversed, both features resulting in a serious increase of pressure loss and decrease of capacity. On the tests that have been made, instances have been noted where the capacity of the meter has been increased from 34 to 95 per cent merely by a change or redesigning of the waterways, leaving the size of the disc, number of mutations, etc., the same (see figs. 1 and 2).

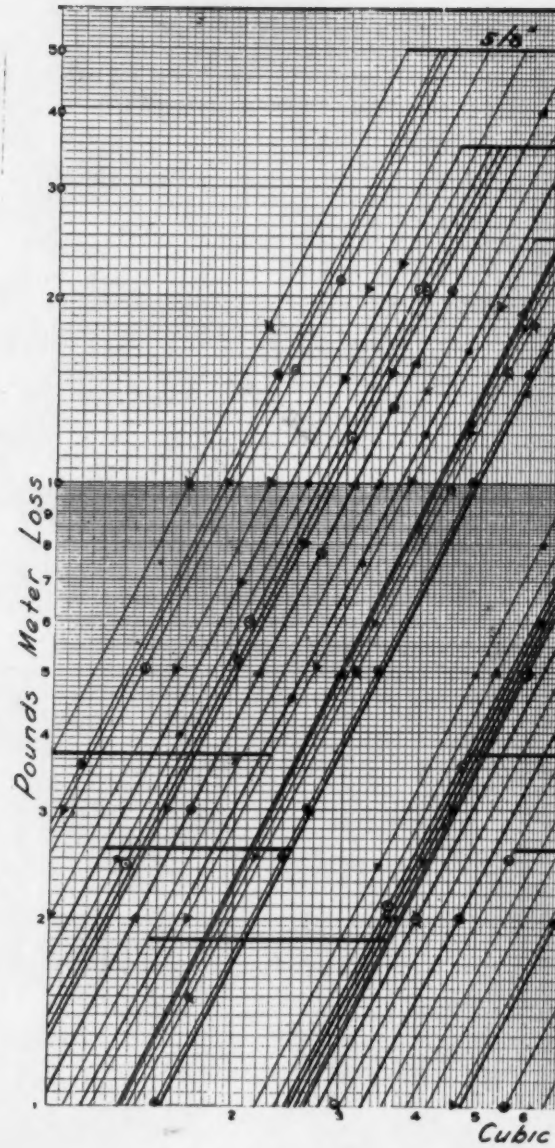
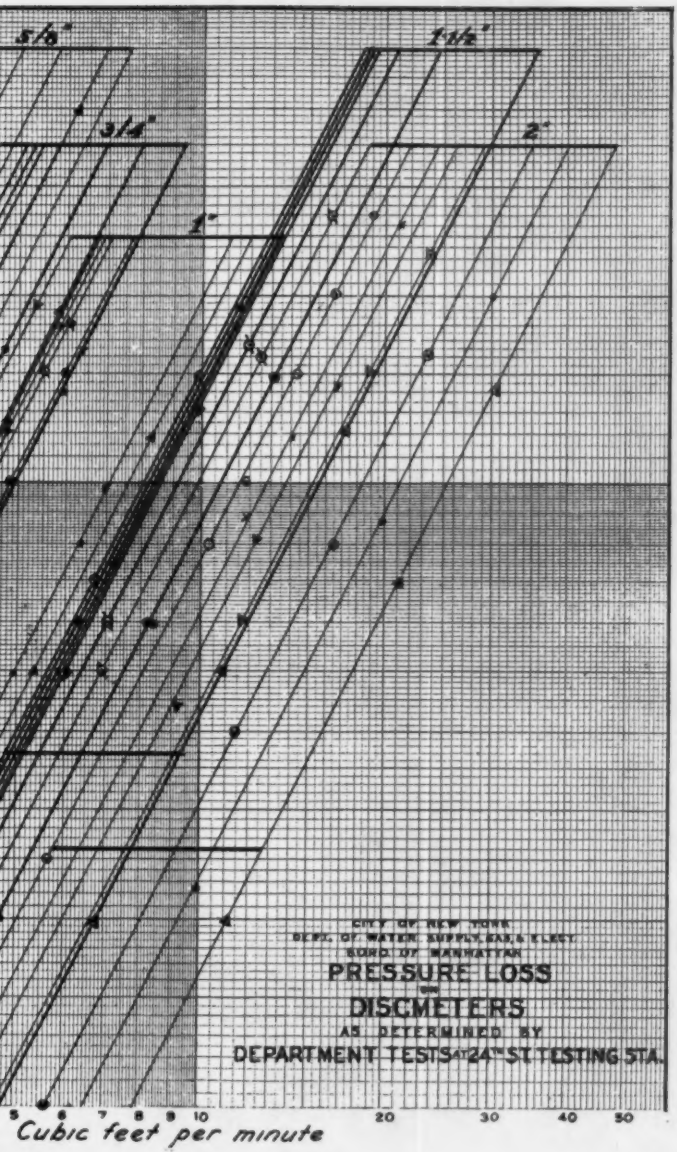


FIG. 5. COMPARATIVE PRESSURE L
FROM ¾ TO 2 INCH

Showing the lack of uniformity in capacity correspo
various sizes may be identified by the shape of points u



ESSURE LOSS OF DIFFERENT MAKES OF METERS
O 2 INCHES IN SIZE, INCLUSIVE

corresponding with the given sizes. (Each individual make in the
f points used in plotting.)

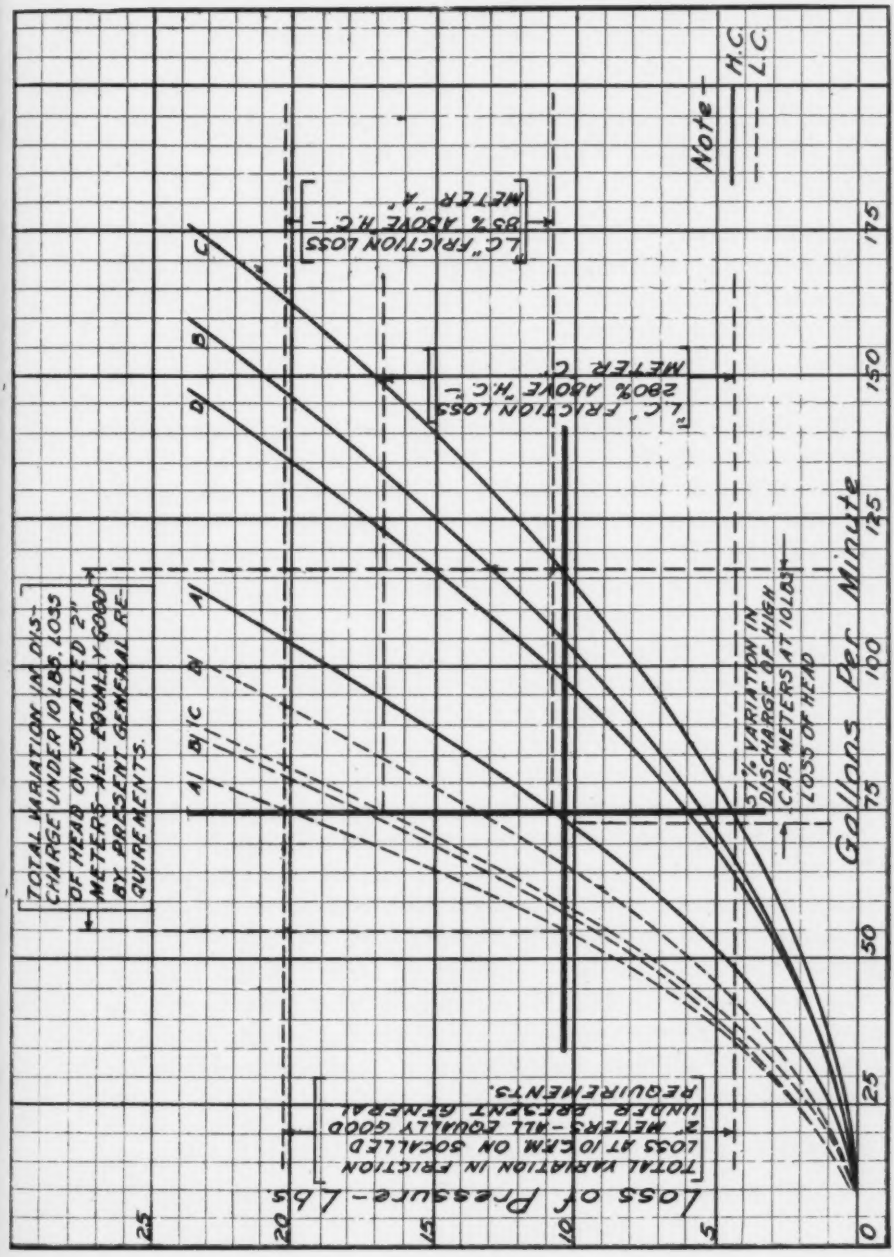

Loss of Pressure - Lbs.
Gallons Per Minute
Note
H.C.
L.C.
A
B
C
D
TOTAL VARIATION IN CHARGE UNDER 10 LBS. LOSS OF HEAD ON SO CALLED 2" METERS - ALL EQUALLY GOOD BY PRESENT GENERAL REQUIREMENTS.
TOTAL VARIATION IN LOSS AT 10 GPM ON SO CALLED 2" METERS - ALL EQUALLY GOOD UNDER PRESENT GENERAL REQUIREMENTS.
L.C. FRICTION LOSS 85% ABOVE H.C. METER "A"
L.C. FRICTION LOSS 280% ABOVE H.C. METER "C"
57% VARIATION IN DISCHARGE OF HIGH CAP. METERS AT 10 LBS. LOSS OF HEAD

FIG. 4. VARIATIONS OF CAPACITY AND LOSS OF HEAD IN FOUR MAKES OF 2-INCH METERS
Full lines are for high-capacity and dotted lines for low-capacity meters.

WATER PURIFICATION PROLEMS[1]

By B. M. Mohler

There are in Minnesota at the present time seventeen public water supplies which are receiving some kind of purification. Nine of these supplies are treated with chlorine gas only, two receive filtration and subsequent disinfection and six are subjected to sedimentation, filtration and disinfection.

The Duluth water supply is the only one of the group treated with chlorine only, the treatment of which is not difficult to properly control, the Lake Superior water showing only slight variations in physical characteristics. The other eight supplies in this group show considerable seasonal variation in organic content and are difficult of proper control, especially wherever facilities for necessary laboratory tests are lacking.

The Minnesota state board of health insists that purification of a contaminated public water supply by disinfection only is merely a temporary expedient and that a suitable system of filtration must be installed as soon as possible to supplement the disinfection treatment.

Seven of the seventeen supplies are treated with calcium hypochlorite solution while the remaining ten are disinfected with liquid chlorine. Trouble has been experienced in five instances by the sticking of the float in the meter of a certain type of chlorinator which necessitated the control of the flow of gas by weighing of the chlorine cylinder at stated intervals. This latter method of control is not accurate when there is any considerable variation in the amount of chlorine gas required. Experience has shown the need of keeping on hand a supply of duplicate parts for chlorinators. A duplicate chlorinator is desirable for use in cases of emergency.

[1] Abstract of paper before the Minnesota Section, November 10, 1917.

AMERICAN WATER WORKS LABORATORIES[1]

By Jack J. Hinman, Jr.

The water works laboratory as an integral part of the up-to-date water works plant is so well established and has proved itself so useful that any attempt on the author's part to justify its existence is unnecessary. It is only where the small size of the plant forbids the expense attached or where an invariable ground water is supplied that the lack of daily laboratory control should be excused.

While an experienced operator will probably be able to judge the character of the water supply on most occasions, there are, nevertheless, times when a clear, sparkling water may be carrying large numbers of bacteria some of which may be pathogens, or disease-producing forms. The only way to know the quality of the effluent is to submit it to a laboratory examination. At best the delays incident to cultural methods are considerable, but to pump a dangerous water until typhoid cases commence to develop in a community before having examinations undertaken is inexcusable. The number of examinations which it is advisable to make will depend, naturally, on the supply. If the supply is from deep wells, fewer examinations will be required than where the supply is from shallow wells and infiltration galleries. Where a polluted water is coagulated and filtered, examinations should be made even more frequently than in the case of the shallow wells and infiltration galleries. It should be remembered that a dangerous water is being treated and that the character of the effluent may change from day to day or even from hour to hour.

Then, too, the mere installation of a laboratory does not confer immunity from raw water troubles or even from the more serious difficulties. An accumulation of glassware collecting dust is of no value, neither is an accumulation of figures which have no significance from the standpoint of the quality of the effluent or of the effective operation of a plant. Most analysts run a few thousand nitrogen determinations on the raw water before realizing that the

[1] Read before the Iowa Section, October 10, 1917.

results do not vary enough from day to day to be of any practical value. To run them as a routine measure in such cases is a waste. Under certain conditions, of course, there may be considerable daily variations in the nitrogen factors. It is essential that the variable factors be recognized, so that changes in the raw water may be detected and the treatment altered to meet the new conditions. More elaborate examinations of the treated water are justified as giving additional evidence as to its satisfactory character.

For some time the author has been curious to know about the water laboratories which serve the various water plants directly. He was not so much interested in the laboratories that did work under contract or with those that made occasional examinations. He wished to know what plants maintained laboratories, how extensive they were, how they were organized, what their routine procedures were and what results were obtained. He sent out a very comprehensive questionnaire to all cities of over 25,000 population in the United States and Canada, as well as to some smaller places where he knew laboratories were maintained or rapid sand filtration plants installed. Only those which reported plant or department laboratories are included in this report. Contract laboratories and plants operating without laboratory control are not included in the tables.

The percentage of replies was very good. There are only four or five towns of special interest which failed to answer the letters. The author has data on an average daily pumpage of more than 3,000,000,000 gallons, of which more than 2,800,000,000 gallons, supplying cities and towns of a total population of about 17,000,000 in 1910, is protected by laboratory control directly under the supervision of the water works officials or their superior officers.

In the control of the 96 plants which supply the 2,800,000,000 gallons of water daily, 203 laboratory workers are employed. Of these, 95 have the title of chemist or assistant chemist, many of the others have the title superintendent of filtration or laboratory director, and so on. Some of these men have had chemical training. Some are engineers who have picked up the rudiments of water examination and carry on such determinations as are necessary for their plants. The preponderance of one-man laboratories is significant and the variety of the work which must be performed is worthy of notice. In addition to the widely differing subjects of bacteriology, microbiology and chemistry of water, miscellaneous chemical

TABLE 1

American Water Works Laboratories. (Routine)

STATE	CITY	POPULATION IN 1910	AVERAGE DAILY SUPPLY MILLIONS OF GALLONS	SOURCE	OWNERSHIP	TITLE OF LABORATORY CHIEF	HIS IMMEDIATE SUPERIOR	ADDITIONAL LABORATORY WORKERS			CIVIL SERVICE	BACTERIOLOGICAL PROCEDURE				PLANKTON EXAMINATIONS	
								Chemists	Bacteriologists	Helpers		Counting		B. coli tests			
												37 °C.	20° C. to room temperature	Fermentation media	Confirmatory		
California	Los Angeles	319,198	75.0	Aqueduct and River	Municipal	Laboratory director	Commissioner	1	.....	.....	Yes	†	†	.....	Gas; endo; gelatine	Yes	N
	Pasadena	30,291	5.8	Ground and surface	Municipal	City chemist	Commissioner public works	1	.....	.....	No	Agar 48 hours	Agar 48 hours, room temperature	Lactose bile	Gas; Litmus lactose agar	No	O
Colorado	Colorado Springs	29,078	6.1	Mountain streams and reservoir	Municipal	City chemist and bacteriologist	Commissioner public health	.....	.....	.....	Yes	Agar 24 hours	Agar 48 hours, 22°C.	.....	Gas; L. lactose agar; lactose milk; gelatine	No	Sa
	Denver	213,381	52.0	Lake Cheesman and infiltration	Private	Chemist	.....	.....	.....	.....	.....	Agar 24 hours	Gelatine 48 hours, 20°	Lactose bile Lactose broth	Gas; L. lactose agar; lactose broth		Sa
Connecticut	Hartford	98,915	11.1	Six reservoirs	Municipal	Chemist and bacteriologist	Chief engineer	1	.....	.....	.....	.....	.....	.....	.....		C
District of Columbia"	Washington	331,069	59.9	Potomac River	U. S. Government	Chemist	Superintendent	1	.....	2	Yes	.....	Gelatine 48 hours	.....	"Confirmatory"	Yes	N
Georgia	Atlanta	154,839	18.1	Chattahoochee River	Municipal	Chemist	General manager	.....	.....	.....	No	Agar 24 hours	.....	Lactose broth	.....	No	Al
	Columbus	20,554	2.3	Chattahoochee River	Municipal	Assistant superintendent	Engineer and superintendent	.....	.....	.....	No	Agar 24 hours	.....	Lactose broth	Gas; L. lactose agar; lactose broth	Will	Al
Illinois	Cairo	14,548	4.25	Ohio River	Private	Manager and superintendent	.....	.....	.....	2	No	Agar 24 hours	.....	Lactose broth Lactose bile	5 per cent gas	Occasionally	Al
	Chicago	2,185,283	700.0	Lake Michigan	Municipal	Director municipal laboratories	Commissioner of health	.....	.....	3	Yes	Agar 24 hours	Agar and gelatine 48 hours	Dextrose broth Lactose bile	Gas; indol; esculin; endo plates	No	Ni
	Danville	27,871	5.37	North Fork Vermillion River	Private	Chief engineer	Superintendent	.....	.....	1	No	Agar 24 hours	.....	.....	Endo	No	Al
	Decatur	31,140	3.93	Sangamon River	Municipal	City chemist	Commissioner	.....	.....	.....	No	Agar 24 hours	Gelatine 48 hours, 20°	.....	Gas	No	Ni
	Elgin	25,976	1.50	Five wells, 42 feet to 2000 feet.	Municipal	(In city laboratory)	.....	.....	.....	.....	.....	Agar —	.....	Dextrose broth	Gas; endo; morphology	No	Iro
	Evanston	24,978	8.5	Lake Michigan	Municipal	Superintendent of filtration	Commissioner public works	.....	.....	1	Yes	L. Lactose and plain agar 24 hours	Gelatine 48 hours, 20°	Lactose broth	Gas and acid colonies	Yes	A
	Moline	24,199	4.0	Mississippi River	Municipal	City chemist	Commissioner public property	.....	.....	.....	No	.....	Agar 48 hours, 20°	Dextrose broth	10 per cent gas	Quarterly	Sa
	Quincy	36,587	2.0	Mississippi River	Municipal	Superintendent	Board water commissioners	.....	.....	.....	No	Agar 24 hours	.....	Lactose broth	10 per cent gas	No	Al
	Streator	14,253	.....	Vermillion River	Private	Chief engineer	.....	.....	.....	.....	.....	Agar —	.....	Dextrose broth	Gas	No	No
	Evansville	69,647	9.0	Ohio River	Municipal	Chemist	General manager	.....	.....	.....	No	Agar —	Gelatine 20°	Lactose broth	Gas; endo; bile	Occasionally	Al
Indiana	Ft. Wayne	63,933	6.0	Deep wells	Municipal	(In city laboratory)	.....	.....	.....	.....	.....	.....	.....	Lactose and glucose media	.....	No	No
	Indianapolis	233,650	24.31	Filtered surface and deep wells	Private	Superintendent of filtration	General manager	2	.....	2	.....	Agar 24 hours	Gelatine 20°	.....	†1917	No	San
	Terre Haute	58,157	5.0	Wabash River	Private	Chief engineer	Water Company	.....	.....	1	.....	Agar, maximum development	Gelatine, maximum development	.....	Gas. U. S. P. H. method	No	Alk
	Valparaiso	6,087	0.8	Chain of small lakes	Private	Chief engineer	.....	.....	.....	.....	.....	Agar —	Gelatine —	Lactose bile	20 per cent gas; L. lactose agar; endo; indol	No	Alk
Iowa	Cedar Rapids	37,811	3.0	Cedar River and 1500 feet wells	Municipal	Sanitary engineer and city chemist	Boards water commissioners and health	.....	.....	.....	.....	Agar 24 hours	Gelatine 48 hours	Lactose broth	10 per cent gas	Seldom	Alk
	Council Bluffs	29,992	3.25	Missouri River	Municipal	Chemist	Superintendent	.....	.....	.....	No	.....	Agar 72 hours, room temperature	Lactose broth	Gas in 72 hours	No	San
	Davenport	43,028	4.14	Mississippi River	Private	Chief engineer (under consulting chemist)	Superintendent	.....	.....	.....	.....	.....	Gelatine 48 hours, 20°	.....	.....	No	Alk
	Des Moines	86,386	6.9	Ground water, Valley of Raccoon River	Private	Chief chemist	Superintendent	1	.....	.....	.....	Agar 48 hours	Agar 72 hours, 20°	Lactose broth	U. S. P. H. method	No	Fe,
Kansas	Atchison	16,429	1.2	Missouri River	Private	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Alk
Kentucky	Louisville	223,928	26.0	Ohio River	Municipal	Superintendent of filtration	Chief engineer	1	1	.....	No	L. lactose agar 24 hours	Gelatine 48 hours	Lactose bile	10 per cent gas, "complete isolation"	Occasionally	Alk
Louisiana	Morgan City	5,477	0.25	Atchafaloya River	Municipal	Superintendent water purification stations	Council	.....	.....	.....	No	Agar 24 hours	.....	Broth	5 per cent gas	No	Alk
	New Orleans	339,075	30.0	Mississippi River	Municipal	Superintendent	General superintendent sewerage and water board	2	1	.....	Yes	Agar 24 hours	Gelatine 48 hours, 20°	.....	U. S. P. H. method	No	Alk
Massachusetts	Brockton	56,878	2.9	Silver Lake	Municipal	City Bacteriologist and chemist	Superintendent	1	.....	1	Yes	Agar (L. lactose) 24 hours	.....	.....	Gas; indol	Yes	Fe,
	Lowell	106,294	6.0	2½-inch driven wells	Municipal	Engineer in charge filtration	Superintendent and commissioner	1	.....	.....	Yes	.....	.....	.....	.....	No	Fe,
Michigan	Bay City	45,166	7.0	Saginaw River and Bay	Municipal	Chemist	Superintendent	.....	.....	.....	No	.....	"Bacterial count"	Lactose broth	Gas; endo; agar slant	Yes	Av
	Grand Rapids	112,571	12.35	Grand River	Municipal	Chief chemist and superintendent	Board of public works	3	.....	.....	No	Agar 24 hours	Agar 48 and 72 hours, 20° Gelatine 48 hours, 20°	Lactose broth	†1917	Yes	Alk
Minnesota	Minneapolis	301,408	30.0	Mississippi River	Municipal	Chemist and assistant superintendent	Superintendent purification division	.....	1	1	Yes	Agar 24 hours	Agar 48 and 72 hours, 20° Gelatine 48 hours, 20°	Lactose broth	Gas; run through sugars, etc	Weekly	Alk
Missouri	St. Louis	687,029	98.0	Mississippi River	Municipal	Chemist	Engineer in charge supply and purification division	2	2	4	Efficiency board	Agar 24 hours	Gelatine 72 hours	Lactose broth	Gas; endo; lactose broth	No	Alk
	Springfield	35,201	4.0	Springs and deep wells	Private	.....	Company	3	.....	.....	.....	.....	Gelatine 48 hours, 20°	Lactose broth	10-70 per cent gas; 50 per cent of this in 24 hours	.....	Alk
Nebraska	Omaha	124,096	20.0	Missouri River	Municipal	Sanitary chemist	General manager	1	.....	.....	No	.....	Gelatine 48 hours, 20°	Lactose broth	20-70 per cent gas in 48 hours	No	Alk
New Jersey	Paterson, etc.	125,600	37.0	Passaic River	Private	Superintendent filtration and pumping	Company	1	.....	1	.....	Agar 24 hours	Gelatine 20°	.....	Gas; agar; indol; nitrate; milk	No	Da
	Trenton	96,815	17.5	Delaware River	Municipal	Superintendent filtration	Director Street and Public Improvement	.....	.....	1	Yes	.....	Agra 48 hours, 20°	Broth	Gas; endo	No	CO
New York	Albany	100,253	20.0	Hudson River	Municipal	Chemist	Contract chemist	2	.....	1	Yes	Agar 24 hours, 40°	Gelatine 48 hours, 20°	Dextrose broth and bile	Gas; L. lactose agar, indol; gelatine	Summer only	Da
	Auburn	34,668	6.5	Owasco Lake	Municipal	City bacteriologist	City health and water departments	.....	.....	.....	Yes	Agar 24 hours	Gelatine 48 hours, 20°	Lactose bile	Gas	No	No
	Kingston	25,908	4.5	Sawkill Creek	Municipal	Chemist and bacteriologist	City Superintendent	.....	.....	.....	.....	Agar 24 hours	Gelatine 72 hours, 20°	.....	Gas 48 hours, 20-70 per cent; 50 per cent in 24 hours	Yes	Alk
	Mt. Vernon	30,919	2.5	River	Private	Engineer	Superintendent	.....	.....	.....	.....	.....	Agar 48 hours, 20°	Lactose bile	Gas	No	No
	Newburgh	27,805	5.13	Lake	Municipal	Superintendent of water shed	City manager	.....	.....	.....	Yes	Agar 24 hours	.....	Lactose bile	Gas in 48 hours	.....	No
	New York	4,766,883	550.0	Surface and ground supplies	Municipal	Two directors of laboratory	Chief engineer	3	3	12	Yes	Agar 24 hours	.....	Lactose bile	Gas in 72 hours, 30 per cent	Yes	San
	Niagara Falls	30,445	10.5	Niagara River	Municipal	Chemist in charge operation	Superintendent public service	.....	.....	1	Yes	.....	Gelatine 48 hours, 20°	Lactose bile	Gas † 2nd Edn.	No	Alk
	Poughkeepsie	27,936	2.54	Hudson River	Municipal	Bacteriologist	Commissioners and superintendent public works	.....	.....	.....	Yes	Agar 24 hours	Gelatine 48 hours, 20°	Lactose bile	Gas in 48 hours	No	Alk
	Schenectady	72,826	11.16	Three dug wells	Municipal	City chemist	.....	.....	.....	.....	.....	.....	Agar 48 hours, 20°	.....	.....	.....	Occ
	Syracuse	137,249	.....	Skaneatles Lake	Municipal	City Bacteriologist	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Utica	74,419	12.5	West Canada Creek, etc.	Private	Biologist	Executive committee of company	.....	.....	1	.....	Agar 24 hours	Gelatine 24 and 48 hours	Lactose bile	Gas	No	Alk
	Watertown	26,730	5.5	Black River	Municipal	Superintendent water purification plant	Board water works	.....	.....	.....	Yes	.....	Gelatine, 20°	Lactose bile	Gas	No	Alk
	Yonkers	79,803	9.0	Nepperhan River, Grassy Sprain Branch	Municipal	Chemist department public works	Commissioner public works	1	.....	.....	Yes	.....	Gelatine, 30°	.....	20-70 per cent gas; 25-40 per cent CO_2	Occasionally	Co
North Carolina	Wilmington	25,743	3.0	Cape Fear River	Municipal	Director, board of health laboratory	Board of health	.....	.....	.....	No	.....	.....	.....	†	Seldom	Alk
Ohio	Akron	69,069	20.0	Cuyahoga River	Municipal	Chief chemist	Superintendent	1	.....	1	Yes	L. lactose and plain agar 24 hours	Gelatine, 20°	Lactose bile	15 per cent gas, L. lactose agar	Yes	Alk
	Alliance	15,083	6.0	Mahoning River	Municipal	City chemist	Director public service	.....	.....	.....	Yes	L. lactose and plain agar 24 hours	Agar 48 hours, 20°	Lactose bile	Gas 10 per cent	Occasionally	Alk
	Bucyrus	8,122	1.5	Reservoir	Private	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	No
	Cincinnati	363,591	50.0	Ohio River	Municipal	Bacteriologist and chemist	Superintendent filtration	1	.....	1	.....	.....	Gelatine 48 hours, 20°	Lactose bile	Gas endo; lactose broth; gelatine; Gram, morphology	Occasionally	Alk
	Cleveland	560,663	96.0	Lake Erie	Municipal	Chief chemist and bacteriologist	Superintendent filtration	.....	1	2	Yes	Agar 24 hours	.....	Lactose broth	Gas; endo; lactose broth; gelatine; Gram; morphology	Occasionally	Alk
	Columbus	181,511	20.0	Scioto River	Municipal	Chemist in charge	Superintendent	3	.....	.....	Yes	Agar 24 hours	— 48 hours, 20°	Lactose	Gas in bile; broth; saccharose, dulcite	No	Alk
	Dayton	116,577	12.9	Deep wells	Municipal	Chemist and bacteriologist	Commissioner health	1	.....	1	.....	Agar 24 hours	Agar 48 hours, 20°	Lactose broth	5 per cent gas; endo; Lactose broth; 5 per cent gas	No	Hi
	Donison	4,008	2.0	Big Stillwater Creek	Private	Superintendent	Directors of company	.....	.....	.....	.....	Agar —	Gelatine —	Lactose broth	.....	No	Alk
	Lima	30,508	3.5	Ottawa River	Municipal	City chemist	Service director	.....	.....	.....	No	.....	Agar, room temperature	Dextrose broth Lactose bile	Gas in bile and broth, gelatine, nitrate, indol	No	No
	Niles	8,361	1.5	Mahoning River	Municipal	Filtration expert	Superintendent	.....	.....	.....	No	Agar —	Gelatine	.....	Gas in 48 hours	No	Alk
	Sandusky	19,989	4.5	Sandusky River	Municipal	Chemist in charge	City manager	.....	.....	.....	Yes	.....	Agar 48 hours, 20°	Lactose bile	Gas	No	Alk
	Steubenville	22,381	4.2	Ohio River	Municipal	Chemist in charge	Superintendent	.....	.....	.....	Yes	L. lactose and plain agar 24 hours	Agar 48 hours, 20°	Lactose bile	Gas; acid colonies; gas; indol	No	Alk
	Toledo	168,497	21.8	Maumee River	Municipal	Chemist in charge	Commissioner division water	3	.....	.....	Yes	Agar 24 hours	Gelatine 48 hours, 20°	Lactose broth	Gas; indol; lactose broth; gelatine	No	Alk
Oregon	Portland	207,214	65.0	Bull Run Lake	Municipal	City and state bacteriologist	City health officer	.....	1	.....	No	.....	Agar 48 hours	Lactose bile	Gas; acid and gas in L. lactose agar	No	No
Pennsylvania	Allentown	51,913	12.0	Springs	Municipal	City chemist and bacteriologist	Council	.....	.....	.....	No	Agar 48 hours	Agar 48 hours	Lactose bile	25 per cent gas; Conradi-Drigalski	No	Ch
	Erie	66,525	19.0	Lake Erie	Municipal	Superintendent filtration	Commissioners	.....	.....	1	No	Agar 72 hours	Gelatine 72 hours, 20°	Lactose broth	Gas; L. lactose agar; indol; gelatine; sugars	Occasionally	Alk
	Lancaster	47,227	7.23	Conestoga Creek	Private	City chemist and bacteriologist	Company	.....	.....	.....	.....	.....	Gelatine 48 hours, 20°	Lactose bile	5 per cent gas	.....	He
	McKeesport	42,694	5.0	Youghiogheny and Monongahela Rivers	Municipal	Chemical engineer	Superintendent department public safety	2	.....	1	No	L. lactose agar 24 and 48 hours	Gelatine 48 and 72 hours, 20°	Glucose broth Lactose broth	15 per cent gas in either	No	Alk
	Philadelphia	1,549,008	300.0	Delaware and Schuylkill Rivers	Municipal	Two chemists in charge laboratories	Chief bureau of water	*	*	*	Yes	Agar 24 hours	Gelatine 48 hours	.....	Fermentation lactose and dextrose	Yes	.....
	Reading	96,071	12.62	Creeks, springs, etc.	Municipal	Chemist	Chief engineer	.....	.....	.....	No	.....	Gelatine 48 hours, 20°	.....	"Presumptive"	Yes	Se
Rhode Island	Newport	27,149	6.5	Impounded surface	Private	Bacteriologist and chemist	General superintendent	.....	.....	.....	No	Agar —	Agar 20°	Lactose bile	Gas; L. lactose agar	Yes	Al
	Providence	224,326	22.5	Pawtuxet River	Municipal	Bacteriologist	City engineer	.....	.....	.....	No	Agar 24 hours	.....	.....	Gas; plate; fermentation tube; indol; gelatine stab	Yes	W
South Carolina	Charleston	58,833	6.25	Reservoir	Private	Superintendent pump and filter plant	Vice president of company	.....	.....	1	.....	Agar 24 hours	.....	Lactose broth	Gas; L. lactose agar	Yes	Al
	Columbia	26,319	5.5	Congoree River	Municipal	.....	Superintendent water department	.....	.....	.....	No	Agar 24 hours	Agar 20°	Lactose bile	Gas	No	Al
South Dakota	Huron	5,791	0.5	James River	Municipal	Operator	Consulting biologist	.....	.....	.....	No	Agar —	.....	Lactose bile	Gas	Yes	N
Tennessee	Nashville	110,364	13.0	Cumberland River	Municipal	City bacteriologist and chemist	City health officer	.....	1	1	Yes	†	.....	.....	†	No	Se
Texas	Dallas	92,104	7.5	.....	Municipal	Superintendent water purification	Commissioner of water	1	.....	.....	No	L. lactose and plain agar occasionally	Gelatine 48 hours, 20°	Lactose bile	†	No	Al
	Ft. Worth	73,312	5.0	Trinity River	Municipal	Superintendent filtration	Commissioner water and sewerage	.....	.....	.....	No	Agar 24 hours	.....	Lactose bile	Gas 20-70 per cent "confirm occasionally"	No	Al
Virginia	Lynchburg	29,494	6.0	Impounding reservoir	Municipal	Health officer and chemist	Council and board of health	1	.....	.....	.....	Agar —	.....	Lactose broth	U. S. P. H. method	Yes	Al
	Richmond	127,628	13.35	James River	Municipal	Director settling basins and laboratories	Superintendent	.....	.....	1	No	Agar —	.....	Lactose broth	Gas	No	Al
Washington	Spokane	104,402	32.0	.....	Municipal	City chemist	Commissioner public utilities	2	.....	.....	Yes	†	.....	.....	†	No	Sa
Wisconsin	Appleton	16,773	4.0	Fox River	Municipal	Superintendent filtration	City commissioners	.....	.....	.....	No	L. lactose agar 24 hours	Agar 48 hours, 20°	Lactose broth	.....	In summer	Al
	Milwaukee	373,859	54.88	Lake Michigan	Municipal	Water works chemist	Superintendent	.....	.....	.....	Yes	Agar 48 hours	Gelatine 48 hours, 20°	.....	5 per cent gas	No	.....
	Superior	40,384	2.3	Shallow wells	Private	Assistant engineer	General superintendent	.....	.....	1	.....	Agar 24 and 48 hours	Gelatine 96 hours, room temperature	Lactose broth	Gas; L. lactose plate; broth; morphology	No	In
Canada	Edmonton, Alb.	30,855	5.25	Saskatchewan River	Municipal	Head operator	Superintendent	.....	.....	.....	No	.....	Agar 48 hours	.....	.....	.....	N
	Montreal, P. Q.	450,273	55.0	St. Lawrence River	Municipal	Chemist	Engineer superintendent	1	.....	.....	No	.....	Agar 96 hours, 20°	Lactose bile Dextrose broth	90 per cent bile fermentations	No	Al
	Montreal, P. Q.	.....	30.0	St. Lawrence and Ottawa Rivers	Private	Sanitary engineer	General manager	1	.....	.....	.....	Agar 24 hours	Agar 48 hours, 20°	Lactose bile	Gas	No	Al
	Ottawa, Ont	73,193	24.0	Ottawa River	Municipal	City bacteriologist and chemist	Board of health	.....	.....	2	No	Agar 24 hours	Agar 72 hours, 20°	Lactose bile	Gas; neutral red bile salt agar; lactose fermentation; non spore former	Yes	Al
Georgia	Commerce	.....	0.125	Small stream	Municipal	Superintendent	City water commission	.....	.....	.....	No	Agar 24 hours	.....	.....	Presumptive	.....	Al
	La Grange	.....	0.30	Creek	Municipal	City engineer	.....	.....	.....	.....	.....	.....	.....	Lactose bile	.....	.....	Ty
	Milledgeville	.....	0.25	Creek	Private	Engineer	Superintendent	.....	.....	.....	.....	.....	Agar 48 hours, 20°C.	.....	50 per cent gas in 48 hours	No	.....
Michigan	Dearborn	.....	0.10	River Rouge	Private	Chemist	.....	.....	.....	1	No	†	†	†	†	.....	.....
Canada, British Columbia	New Westminster	.....	9.0	Mountain Lake	Municipal	.....	.....	.....	.....	.....	.....	.....	Count 48 hours	.....	.....	No	.....
Philippine Islands	Manila	.....	17.0	Mariquima River	Municipal	Bureau of science	.....	.....	.....	.....	Philippine civil service	Agar 24 hours	.....	Lactose	Acid and gas in L. lactose agar	No	.....

* Number not given.

† Specified only "A. P. H. A. Methods."

TABLE 1

American Water Works Laboratories. (*Routine*)

IMMEDIATE SUPERIOR	ADDITIONAL LABORATORY WORKERS: Chemists	ADDITIONAL LABORATORY WORKERS: Bacteriologists	ADDITIONAL LABORATORY WORKERS: Helpers	CIVIL SERVICE	BACTERIOLOGICAL PROCEDURE: Counting: 37 °C.	BACTERIOLOGICAL PROCEDURE: Counting: 20° C. to room temperature	BACTERIOLOGICAL PROCEDURE: B. coli tests: Fermentation media	BACTERIOLOGICAL PROCEDURE: B. coli tests: Confirmatory	PLANKTON EXAMINATIONS	CHEMICAL DETERMINATIONS	PHYSICAL DETERMINATIONS	DATE LABORATORY CONTROL BEGUN	EXAMINATIONS OTHER MATERIALS	WORKING STANDARD
	1			Yes	†	†		Gas; endo; gelatine	Yes	Nitrogen, chlorine, total solids, hardness	Turbidity, color, odor, taste	1915	Occasionally	U. S. Treasury Department for interstate carriers
public works	1			No	Agar 48 hours	Agar 48 hours, room temperature	Lactose bile	Gas; Litmus lactose agar	No	Occasional complete mineral and sanitary	No	1912	Sewage, food, oils, etc.	"Total bacteria less than 20 per cubic centimeter"
public health				Yes	Agar 24 hours	Agar 48 hours, 22°C.		Gas; L. lactose agar; lactose milk; gelatine	No	Sanitary	Odor, color, taste, etc.	1902	Health department work	"48 hour count under 100"
					Agar 24 hours	Gelatine 48 hours, 20°	Lactose bile Lactose broth	Gas; L. lactose agar; lactose broth		Sanitary analysis once a month	color, turbidity, taste, odor, sediment		No	U. S. Treasury Department for interstate carriers
	1									Complete sanitary	Color, turbidity, taste, odor, sediment	1913	No	"Colon negative in 10 cc."
	1		2	Yes		Gelatine 48 hours		"Confirmatory"	Yes	Nitrogens, hardness alkalinity, chlorine	Turbidity	1915		"As high as possible"
er				No	Agar 24 hours		Lactose broth		No	Alkalinity	Turbidity	1915	Coal, chemicals, etc.	"Under 15 per cubic centimeter"
superintendent				No	Agar 24 hours		Lactose broth Lactose broth	Gas; L. lactose agar; lactose broth	Will	Alkalinity, CO_3	Turbidity, color, odor, taste	1915	Filter chemicals	"As low as possible in bacteria and B. coli"
			2	No	Agar 24 hours		Lactose bile Dextrose broth	5 per cent gas	Occasionally	Alkalinity	Turbidity, color, etc.	1913	Filter chemicals	U. S. Treasury Department
of health			3	Yes	Agar 24 hours	Agar and gelatine 48 hours	Lactose bile	Gas; indol; esculin; endo plates	No	Nitrogens, oxygen consumed, chlorine			Miscellaneous for department	"Free of colon in 10 cc.
			1	No	Agar 24 hours			Endo	No	Alkalinity	Turbidity, color	1912	No	U. S. Treasury Department
				No	Agar 24 hours	Gelatine 48 hours, 20°		Gas	No	Nitrogens, solids, chlorine, oxygen consumed, alkalinity	Turbidity, color, odor	1916	Food, sewage	U. S. Treasury Department
					Agar —		Dextrose broth	Gas; endo; morphology	No	Iron	Sediment		Pathological work	
public works			1	Yes	L. Lactose and plain agar 24 hours	Gelatine 48 hours, 20°	Lactose broth	Gas and acid colonies	Yes	Available chlorine, oxygen dissolved, alkalinity	Turbidity, odor, temperature	1914	No	"Very few colonies on gelatine, no gas in fermentation tubes, no color, turbidity, chlorine, alum
public property				No		Agar 48 hours, 20°	Dextrose broth	10 per cent gas	Quarterly	Sanitary monthly, mineral quarterly, alkalinity, hardness	Turbidity, odor, temperature	1903	Health and street departments	"Bacteria near 0, gas absent in 1 cc. and 4/5 of 10 cc. tubes, color 15 turbidity 0"
missioners				No	Agar 24 hours		Lactose broth	10 per cent gas	No	Alkalinity	Turbidity color	1909	No	"Agar count below 50; B. coli absent in 10 cc."
					Agar —		Dextrose broth	Gas	No	No		1910		"Below a count of 50 bacteria in 1 cc. and negative gas tests"
er				No	Agar —	Gelatine 20°	Lactose broth	Gas; endo; bile	Occasionally	Alkalinity, CO_3: hardness, Mg. monthly	Turbidity, color, odor, temperature	1912		U. S. Treasury Department
							Lactose and glucose media		No	No	Odor, sediment		Health department work	
er	2		2		Agar 24 hours	Gelatine 20°		†1917	No	Sanitary and mineral analyses	Turbidity, color, odor, taste	1904	Coal, sand, chemicals	U. S. Treasury Department
y			1		Agar, maximum development	Gelatine, maximum development		Gas. U. S. P. H. method	No	Alkalinity, chlorine, CO_3, hardness	Turbidity, color, odor, taste, temperature	1908	No	"Bright and clear"
					Agar —	Gelatine —	Lactose bile	20 per cent gas; L. lactose agar; endo; indol	No	Alkalinity. Occasionally CO_3, NO_3, chlorine, Fe	Color	1909	No	U. S. Treasury Department
missioners and health					Agar 24 hours	Gelatine 48 hours	Lactose broth	10 per cent gas	Seldom	Alkalinity, chlorine, oxygen consumed	Turbidity, color, odor, taste	1912	Milk, gas, etc.	U. S. Treasury Department
				No		Agar 72 hours, room temperature	Lactose broth	Gas in 72 hours	No	Sanitary two to three times month	Color, suspended matter	1909	Coal, chemicals	"No gas-forming bacteria; less than 50 bacteria per cubic centimeter as little color and turbidity as possible"
						Gelatine 48 hours, 20°			No	Alkalinity	Turbidity, color	1910	No	"As nearly sterile as possible"
	1				Agar 48 hours	Agar 72 hours, 20°	Lactose broth	U. S. P. H. method	No	Fe, hardness daily; sanitary two per week; mineral two per year	Color, turbidity, odor, taste	1911	Sand, milk	"No fermentation in 10 cc.; 75 bacteria per cubic centimeter at 20°C"
										Alkalinity	Turbidity			
	1	1		No	L. lactose agar 24 hours	Gelatine 48 hours	Lactose bile	10 per cent gas, "complete isolation"	Occasionally	Alkalinity 2 times day; sanitary weekly; mineral monthly	Turbidity, temperature	1909	Sand, chemicals	"Less than 100 bacteria per cubic centimeter; no B. coli in two 1 and two 10 cc. plantings"
				No	Agar 24 hours		Broth	5 per cent gas	No	Alkalinity, chlorine	Turbidity, color	1916	No	"Negative for B. coli; 98 to 100 per cent bacteria removal; turbidity 0"
tendent sewerage and water board	2	1		Yes	Agar 24 hours	Gelatine 48 hours, 20°		U. S. P. H. method	No	Alkalinity, CO_3, chlorine, incrustants, solids	Turbidity, color, odor	1909	Supplies	U. S. Treasury Department
	1		1	Yes	Agar (L. lactose) 24 hours			Gas; indol	Yes	Fe, sanitary	Turbidity, color	1906	General city work	
and commissioner	1			Yes					No	Fe, alkalinity, Mn, CO_3, dissolved oxygen	Turbidity, color	1915	No	Fe and Mn absent (plant for Fe and Mn removal only)
				No		"Bacterial count"	Lactose broth	Gas; endo; agar slant	Yes	Available chlorine, oxygen consumed	Turbidity, taste	1916	General bacterial work	
works	3			No	Agar 24 hours	Agar 48 and 72 hours, 20° Gelatine 48 hours, 20°	Lactose broth	†1917	Yes	Alkalinity, Mg, incrustants, hourly to 3 times day	Turbidity, color, odor (hot and cold,	1912	General city work	"Alkalinity and turbidity; hardness as low as raw water permits, Mg controlling factor"
purification division		1	1	Yes	Agar 24 hours	Agar 48 and 72 hours, 20° Gelatine 48 hours, 20°	Lactose broth	Gas; run through sugars, etc	Weekly	Alkalinity, hardness, CO_3, dissolved oxygen, monthly sanitary and mineral	Turbidity, color, taste	1913	No	"Colony count 10 or less; B. coli absent in 10 cc.; color 10; turbidity taste, odor 0"
supply and purification division	2	2	4	Efficiency board	Agar 24 hours	Gelatine 72 hours	Lactose broth	Gas; endo; lactose broth	No	Alkalinity, Ma, Ca, solids, sanitary weekly, mineral 2 times monthly	Turbidity, color	1906	Filter chemicals	"Agar count below 50; no B. coli in 50 cc."
	3					Gelatine 48 hours, 20°	Lactose broth	10-70 per cent gas; 50 per cent of this in 24 hours		Alkalinity, chlorine, free chlorine, alum	Turbidity, color	1911	No	"Free from B. coli and bacterial count as low as possible to obtain"
r	1			No		Gelatine 48 hours, 20°	Lactose broth	20-70 per cent gas in 48 hours	No	Alkalinity, chlorine, sanitary	Turbidity, color	1911	Coal, supplies	"Clear, colorless odorless, average count less than 100; B. coli negative in 1 cc."
	1		1		Agar 24 hours	Gelatine 20°		Gas; agar; indol; nitrate; milk	No	Daily CO_3, dissolved oxygen, 2 times day, alkalinity; sanitary monthly	Turbidity, color	1902	No	"Color 10 or less; bacteria 5"
and Public Improvement			1	Yes		Agra 48 hours, 20°	Broth	Gas; endo	No	CO_3, alkalinity	Turbidity, color		Milk	"Turbidity less than 1; color less than 10; bacteria reduction 99.9 per cent; B. coli not over 10 per cent †"
t	2		1	Yes	Agar 24 hours, 40°	Gelatine 48 hours, 20°	Dextrose broth and bile	Gas; L. lactose agar, indol; gelatine	Summer only	Daily CO_3, alkalinity, hardness, chlorine, oxygen consumed, ammonias	Turbidity, color, temperature	1899	Sewage	"Gelatine count under 50; agar under 5; no colonies on neutral red bile agar; not more than 25 per cent of 10 cc. B. coli tubes positive in a year's time"
water departments				Yes	Agar 24 hours	Gelatine 48 hours, 20°	Lactose bile	Gas	No	No	No	1913	No	
dent					Agar 24 hours	Gelatine 72 hours, 20°		Gas 48 hours, 20-70 per cent; 50 per cent in 24 hours	Yes	Alkalinity, hardness, chlorine	Turbidity, color	1912	No	'Gelatine count below 100; color less than 10 p.p.m.; turbidity 0"
						Agar 48 hours, 20°	Lactose bile	Gas	No	No	No	1911	No	"Below an average of 50 bacteria per cubic centimeter"
				Yes	Agar 24 hours		Lactose bile	Gas in 48 hours		No		1915	No	"Free from gas in 10 cc."
	3	3	12	Yes	Agar 24 hours		Lactose bile	Gas in 72 hours, 20 per cent	Yes	Sanitary analyses, alkalinity, solids, etc., total lime	Turbidity, color, temperature	1897	Sand, sewage, research	"As free as possible from B. coli in 10 cc."
public service			1	Yes		Gelatine 48 hours, 20°	Lactose bile	Gas † 2nd Edn.	No	Alkalinity hardness, chlorine	Turbidity, color, temperature		No	"B. coli negative in 10 cc. volumes; count not over 10"
and superintendent public works				Yes	Agar 24 hours	Gelatine 48 hours, 20°	Lactose bile	Gas in 48 hours	No	Alkalinity, chlorine	Turbidity, color temperature, odor	1907	No	"100 per cent"
						Agar 48 hours, 20°				Occasional sanitary examinations			(Two examinations weekly)	
mittee of company			1		Agar 24 hours	Gelatine 24 and 48 hours	Lactose bile	Gas	No	Alkalinity, hardness, chlorine	Turbidity, color, odor, taste	1897	Supplies, etc.	
rks				Yes		Gelatine, 20°	Lactose bile	Gas	No	Alkalinity	Turbidity, color	1904	Occasionally	"Color below 15; bacteria low—less than 20; colon absent"
public works	1			Yes		Gelatine, 20°		20-70 per cent gas; 25-40 per cent CO_2	Occasionally	Complete sanitary monthly	Turbidity	1913	Coal	"No B coli in 10 cc.; total microorganims about 15 to 25 per cubic meter on average"
				No				†	Seldom	Alkalinity, hardness, chlorine, CO_2	Turbidity, color	1912	Diagnostic work	"0.0 per cent B. coli in 10 cc., 37° count below 50; 33° count below 20."
	1		1	Yes	L. lactose and plain agar 24 hours	Gelatine, 20°	Lactose bile	15 per cent gas, L. lactose agar	Yes	Alkalinity, hardness, CO_3, oxygen consumed; mineral monthly	Turbidity, color	1915	Coal	"Free from B. coli in 1 cc. and except occasionally in 10 cc.; 20°count less than 100 per cubic centimeter"
service				Yes	L. lactose and plain agar 24 hours	Agar 48 hours, 20°	Lactose bile	Gas 10 per cent	Occasionally	Alkalinity, incrustants, Fe, CO_2, Mg, oxygen consumed, free chlorine	Turbidity, color	1913	Sewage	"0 turbidity and no colon in 1 cc."
										No	Turbidity			
filtration	1		1			Gelatine 48 hours, 20°	Lactose bile	Gas endo; lactose broth; gelatine; Gram; morphology	Occasionally	Alkalinity, hardness, oxygen consumed, sanitary examinations	Turbidity, color, suspended matter	1907	Supplies	
filtration		1	2	Yes	Agar 24 hours		Lactose broth	Gas; endo; lactose broth; gelatine; Gram; morphology	Occasionally	Alkalinity, chlorine, free chlorine	Turbidity		Supplies	'As low as possible in bacteria without producing odor and taste of chlorine"
	3			Yes	Agar 24 hours	— 48 hours, 20°	Lactose	Gas in bile; broth; saccharose, dulcite	No	Alkalinity, incrustants, CO_3, Mg	Color	1908	City supplies	"B. coli absent in 50 cc.; total numbers below 20"
ealth	1		1		Agar 24 hours	Agar 48 hours, 20°	Lactose broth	5 per cent gas; endo; Lactose broth; 5 per cent gas	No	Hardness, alkalinity, sanitary examinations	Turbidity, color, odor		General city work	"Free of B. coli in 10 cc. and pollution of any kind"
pany					Agar —	Gelatine —	Lactose broth		No	Alkalinity, free chlorine, Fe	Turbidity, color	1915	No	'Negative B. coli in 1 and 10 cc. with not over 50 bacteria per cubic centimeter at 20°C"
				No		Agar, room temperature	Dextrose broth Lactose bile	Gas in bile and broth, gelatine, nitrate, indol	No	No		1911	Milk	"Free from B. coli"
				No	Agar —	Gelatine		Gas in 48 hours	No	Alkalinity, hardness, Fe, etc.	Turbidity, color, temperature		No	"Less than 50 bacteria; free from gas formers in 10 cc."
				Yes		Agar 48 hours, 20°	Lactose bile	Gas	No	Alkalinity; occasionally Fe, chlorine, incrustants	Turbidity, color, temperature	1909	Oil, coal, chemicals	"Less than 50 bacteria per cubic centimeter; no B. coli; free from turbidity; color less than 10"
				Yes	L. lactose and plain agar 24 hours	Agar 48 hours, 20°	Lactose bile	Gas; acid colonies; gas; indol	No	Alkalinity, incrustants, CO_3, $FeSO_4$, $Al_2(SO_4)_3$ occasionally	Turbidity, color	1915	Supplies	"No free CO_2; most of time 8 or 9 p.p.m. bicarbonate alkalinity, sometimes almost caustic"
vision water	3			Yes	Agar 24 hours	Gelatine 48 hours, 20°	Lactose broth	Gas; indol; lactose broth; gelatine	No	Alkalinity, suspended matter, hardness, oxygen consumed, chlorine, Ca, Mg	Turbidity, color, odor, taste, temperature	1910	Coal, filter chemicals	"Four parts monocarbonate alkalinity with iron and lime; three parts free CO_2 with alum treatment"
er		1		No		Agar 48 hours	Lactose bile	Gas; acid and gas in L. lactose agar	No	No	No		General work	
				No	Agar 48 hours	Agar 48 hours	Lactose bile	25 per cent gas; Conradi-Drigalski	No	Complete once month	No	1914	General city work	"No B. coli in 100 cc.
			1	No	Agar 72 hours	Gelatine 72 hours, 20°	Lactose broth	Gas; L. lactose agar; indol; gelatine; sugars	Occasionally	Alkalinity	Turbidity, temperature	1911	Coal supplies	"A sterile water with no turbidity and the color below 5 p.p.m."
						Gelatine 48 hours, 20°	Lactose bile	5 per cent gas		Hardness, Sanitary examinations	Turbidity, color, odor	1906	General city work	"Less than 50"
department public safety	2		1	No	L. lactose agar 24 and 48 hours	Gelatine 48 and 72 hours, 20°	Glucose broth Lactose broth	15 per cent gas in either	No	Alkalinity, hardness, three to twelve times daily	Turbidity, color	1909	Chemicals, etc.	"Turbidity 0; color not more than trace; hardness below 80; no presumptive B. coli in 10 cc."
water	*	*	*	Yes	Agar 24 hours	Gelatine 48 hours		Fermentation lactose and dextrose	Yes		Turbidity, color			"Free from B. coli in 1 and 10 cc."
endent				No		Gelatine 48 hours, 20°		"Presumptive"	Yes	Sanitary	Turbidity	1910	Materials of construction	
				No	Agar —	Agar 20°	Lactose bile	Gas; L. lactose agar	Yes	Alkalinity, occasional sanitary examinations, Fe., alum	Tu bidity, color, odor, sediment	1910	Coal, chemicals	"Bacteria maximum 10; color 10; turbidity 0; alkaliniy 6-7 p.p.m."
				No	Agar 24 hours			Gas; plate; fermentation tube; indol; gelatine stab	Yes	Weekly sanitary (at sewage station)	Color	1905	No	
company			1		Agar 24 hours		Lactose broth	Gas; L. lactose agar	Yes	Alkalinity, chlorine, hardness	Odor	1905	No	"Color 15 p.p.m.; alkalinity 20 p.p.m.; hardness below 50 p.p.m."
water department				No	Agar 24 hours	Agar 20°	Lactose bile	Gas	No	Alkalinity	Turbidity	1906	No	"Count below 25 and removal of all gas-forming organisms presumptive for B. coli"
rist				No	Agar —		Lactose bile	Gas	Yes	No	No	1915	No	"10 colonies; B. coli absent in 10 cc."
er		1	1	Yes	†	†		†	No	Sanitary monthly	Turbidity	1914	General city work	"Bacteria under 50; no B. coli"
water	1			No	L. lactose and plain agar occasionally	Gelatine 48 hours, 20°	Lactose bile	†	No	Alkalinity, hardness, solids	Turbidity	1914	Sewage	
ater and sewerage				No	Agar 24 hours		Lactose bile	Gas 20-70 per cent "confirm occasionally"	No	Alkalinity twelve times daily; hardness daily	Turbidity, color, odor, taste	1912	Paving materials	U. S. Treasury Department
rd of health	1				Agar —		Lactose broth	U. S. P. H. method	Yes	Alkalinity, dissolved oxygen	Turbidity, color, odor		General city work	U. S. Treasury Department
			1	No	Agar —		Lactose broth	Gas	No	Alkalinity	Turbidity, color	1910	No	"Total count 10 and under; B. coli negative in 20 cc. and turbidity under 4; color under 9"
ublic utilities	2			Yes	†			†	No	Sanitary examinations		1910	General city work	
ers				No	L. lactose agar 24 hours	Agar 48 hours, 20°	Lactose broth		In summer	Alkalinity	Turbidity, color, odor		Milk	"Reduction 97 per cent; total absence of B. coli in 10 cc."
				Yes	Agar 48 hours	Gelatine 48 hours, 20°		5 per cent gas	No			1913	Coal, etc.	U. S. Treasury Department
endent			1		Agar 24 and 48 hours	Gelatine 96 hours, room temperature	Lactose broth	Gas; L. lactose plate; broth; morphology	No	Iron	Color, temperature	1906	Sand supplies	"Fe less than 0.3 p.p.m." (primarily for Fe removal)
				No		Agar 48 hours				No		1912	Oil, coal	"As clear and pure as possible"
tendent	1			No		Agar 96 hours, 20°	Lactose bile Dextrose broth	90 per cent bile fermentations	No	Alkalinity	Turbidity, color	1910	Coal, sand, etc.	"Total count less than 20 per cubic centimeter"
	1				Agar 24 hours	Agar 48 hours, 20°	Lactose bile	Gas	No	Alkalinity	Turbidity, color		Miscellaneous	"99.9 per cent"
			2	No	Agar 24 hours	Agar 72 hours, 20°	Lactose bile	Gas; neutral red bile salt agar; lactose fermentation; non spore former	Yes	Alkalinity, electrical conductivity, Fe, CO_2, hardness, sanitary	Turbidity, color		Gas, city work	"Coli under 2 per 100 cc."
mission				No	Agar 24 hours			Presumptive		Alkalinity and CO_3		1915	No	"Absolutely clear and as free of all bacteria as possible"
							Lactose bile			Free alum and chlorine		1915	No	"Standard of the American Public Health Association"
						Agar 48 hours, 20°C.		50 per cent gas in 48 hours	No	Alkalinity	Turbidity	1911	No	"High"
			1	No	†	†	†	†		Alkalinity, hardness, incrustants	Color, turbidity	1915	No	"As near zero in all forms of bacteria as possible"
						Count 48 hours			No	No	No		Milk	
				Philippine civil service	Agar 24 hours		Lactose	Acid and gas in L. lactose agar	No	Mineral and sanitary	Temperature, turbidity, color		Much varied	"Improve as much as possible."

TABLE 2

American Water Works Laboratories. (Plant Data)

STATE	CITY	AVERAGE DAILY PUMPAGE	SOURCE SUPPLY	WORKING STANDARD	ABRUPT CHANGES IN RAW WATER	NO. FILTER UNITS	TYPE FILTERS	RATE OF OPERATION	HOW OFTEN CLEANED	MANNER OF CLEANING	POINT OF CHLORINATION	CONTROL OF DOSAGE OF CHEMICALS	PERIOD OF SEDIMENTATION	STORAGE OF TREATED WATER	CONSUMPTION DETERMINED BY	COLOR		TURBIDITY		18
																Raw	Ttd.	Raw	Ttd.	Raw
		M. G. D.																		
California	Los Angeles	75.0	Aqueduct and river	U. S. T. D.	Seldom	None					Intake	Manual		24 hours		15		5		<1
	Pasadena	5.8	Ground and surface	Total bacteria less than 20 per cubic centimeter	Part	None					Intake	Manual		10 days	Venturi meter	Clear		No		2-5
Colorado	Colorado Springs	6.1	Mountain streams and reservoir	48 hours test under 10 per cubic centimeter	At heavy rains	None										No				3
	Denver	52.0	Lake Cheesman and infiltration	U. S. T. D.	Yes		Slow and rapid sand				After filtration	Automatic			Checked	2-50	0	2-400	0	0-2
Connecticut	Hartford	11.1	Six reservoirs	Colon negative	Moderate	None					Where enters main					15		27		
																28-48	20-36	1-8	Same	
District of Columbia	Washington	59.9	Potomac River	As high as possible	Yes	29	Slow sand	2.5 m.g.a.d.	Av. 71 days	Scrape and rake			4 days	4 hours	Venturi	36	28	4		
Georgia	Atlanta	18.1	Chattahoochee River	Under 15 bacteria per cubic centimeter	Yes	48	36 N. Y. C. Jewell, ¼ m.g.d. 12 Hyatt vertical, ¼ m.g.d.	21-35 m.g.a.d.	30 hrs	Mechanical		Manual	6-10 hours	2 weeks	Venturi	Slight	No	238	0	
	Columbus	2.3	Chattahoochee River	As low as possible in bacteria and B. coli	Very	4	Rapid sand	1 m.g.d. per unit	24 hours	Air and water		Orifice tanks	6 hours	2½ m.g. basin			No	24-900	0	
																Red brown	Clear	10-3000		
	Commerce	0.125	Small stream	Absolutely clear and as free from bacteria as possible	Local rains	1	Rectangular concrete	½ normal	24-30 hours	Air and water		Automatic	2 hours		Revolution counter		5		0	
	Le Grange	0.3	Creek	Standard of American Public Health Association	Yes	3	American Water Softener Co.	346 gallons per minute	When needed	Air and water	Effluent from filters		6 hours	15 hours	Venturi	Red	0	50-4000	0	
	Milledgeville	0.25	Creek	High	Yes	2	Pressure	500,000 gallons	48 hours	Back pressure	Between settling basin and main pump		6 hours	No	Manometer			8-3000	0	
Illinois	Cairo	4.25	Ohio River	U. S. T. D.	Yes	6	N. Y. C. Jewell, tub	Overloaded	4-24 hours	Air and water	Effluent from filters	Manual	3 hours	1 hour	Revolution counter	10-30	0-5	100-3000	15-35	Very h
	Chicago	700.0	Lake Michigan	Free of colon in 10 cc.												0	0	0.120		0
	Danville	5.37	North Fork Vermillion River	U. S. T. D.	Yes	8	Concrete Jewell, 7.5 m.g.	125 m.g.a.d.	6-24 hours	Air and water	Effluent from filters		1 hour	4-6 hours	Pitometer	20-250	0-30	25-2000	0	0-10
	Decatur	3.93	Sangamon River	U. S. T. D.	Yes	6	N. Y. C. J.	1.5 m.g.a.d.	24 hours	Water	Effluent from filters		4-6 hours	18 hours	Venturi on L. S.	0-20	0.10	10-285	0	
	Elgin	1.50	Five wells, 43-2000		No		N. Y.								Revolution counter	12 5-60	3.7	139 10-12		0.5
	Evanston	8.50	Lake Michigan	Very few bacteria. No gas. No color, turbidity, alum, free chlorine	Yes	6	2 m.g. gravity mechanical	100-125 m.g.a. d.	8-48 hours	Air and water	Effluent from filters		2 hours	4 hours	Recording Venturi	6	0	13	0	
	Moline	4.00	Mississippi River	Bacteria, 0; gas absent in 1 cc. and 4/5 10 cc.; color 15; turbidity, 0	Yes	5	Concrete gravity	125 m.g.a.d.	12-40 hours	Air and water	Effluent from filters		2-3 hours	5 hours	Venturi	20-100	5	0-6000	0	Maximum 2
	Quincy	2.00	Mississippi River	Agar count below 50; Coli absent in 10 cc.	Yes	6	N. Y. C. J., 1 m.g. units	120 m.g.a.d.	4-20 hours	Air and water	Suction H. S. pump		4-5 hours	None	Venturi on both H. S. and L. S.	25-50 36.5	5-10 5.6	10-1500 110	0	
	Streator		Vermillion River	Below 50 bacteria in 1 cc., negative gas tests	Very	16	American pressure	1½ feet per minute	24 hours	Water	Effluent from filters		5-8 hours	1.2 hours	Revolution counter	10-120	0.1-20	10-3000	0	
Indiana	Evansville	9.0	Ohio River	U. S. T. D.	Yes	12	Gravity	125 m.g.a. d.	24 hours	Air and water	Coagulated water	Manual	5 hours	3 hours	Venturi	3-12	5	15-4000	0	Traces
	Fort Wayne	6.0	Deep wells		No											Clear		Slight at times		
	Indianapolis	24.31	Surface and deep wells	U. S. T. D.	Yes	6	Slow sand	4-6 m.g.a.d.	25-30 days	Scrape, washing	Effluent from filters	Manual	48 hours	12 hours	Venturi	10-480	5-35	3-338	0-3	0.9-3
	Terre Haute	5.0	Wabash River	Bright and clear	Yes	22	Jewell pressure	90 m.g.a.d.	24 hours	Water			4 hours	None	Tachometer	53	12	39	0	1.9
	Valparaiso	0.8	Chain of small lakes	U. S. T. D.	Seldom	3	Gravity	50 m.g.a.d.	24-36 hours	Air and water	Clear well		2½-3 hours	½-1 hour	Revolution counter	34 36-58	14 20-45	133	0	Small No
Iowa	Cedar Rapids	3.0	Cedar River and 1500 feet wells	U. S. T. D.	Yes	14	12 Tub Jewell; 2 N. Y. C. J.	75 m.g.a.d.	24 hours	Air and water	Effluent from filters		½ hour	3 hours (maximum)	Revolution counter	0-100	0-10	0-3000 90	0	0.3
	Council Bluffs	3.25	Missouri River	Less than 50 bacteria per cubic centimeters. No gas formers		None					After sedimentation		5-6 days	None	Pitometer	0-80	0-60	50-12000	0-50	0.2-0.5
	Davenport	4.14	Mississippi River	As nearly sterile as possible	Yes	12	Pressure	1 gal sq. ft. min.	24 hours	Air and water	After coagulation		24 hours		Revolution counter	15 30-80	10 3-30	2500 3-3000	4 0-15	
	Des Moines	6.9	Infiltration gallery, Racoon Valley	75 bacteria per cubic centimeter; no gas formers	Yes.	None					Effluent gallery	Automatic			Venturi	Trace	None	15	3	0.6
Kansas	Atchison	1.2	Missouri River		Yes							Automatic	1 week	1 week	Revolution counter			400+	5-15	
Kentucky	Louisville	26.0	Ohio River	Less than 100 bacteria; no B. coli in 1 and 10 cc.	Yes	18	Gravity	130 m.g.a.d.	20 hours	Water	After coagulation	Manual	4.8 or 12 hours	24 hours	Revolution counter	0	0	Maximum 600 Average 400	0	2-20 7
Louisiana	Morgan City	0.25	Atchafaloya River	No B. coli; 98 to 100 per cent bacteria removal	No	2	Rapid sand	8,000 gallons per hour	24-48 hours	Air and water			6 hours	6 hours	Revolution counter	10-100	5-50	70-800	0	
	New Orleans	30.0	Mississippi River	U. S. T. D.	No	10	Rapid sand	40-150 m.g.a.d.	2-12 days; 106 hours	Water	Effluent from filters	Automatic	12 hours	None	Venturi	8-20 10	3-6 5	60-2400 600	0-3 0	0.3
Massachusetts	Brockton	2.9	Silver Lake	Do not treat																0.05
	Lowell	6.0	2½ feet driven wells	Remove Fe and Mn. (plant for that purpose)	No	12	6 Coke prefilters 6 Slow sand	Coke—75 m.g.a.d. Sand—10 m.g.a.d.	Coke weekly Sand 40 days	Water Scraping	None used		2 hours	4 hours	Venturi	38	0	25	0	2.25 Minimum 1.9
Michigan	Bay City	7.0	Saginaw River and Bay																	
	Dearborn	0.10	River Rouge	As near 0 bacteria as possible	Yes	4	N. Y. C. J., gravity	¼ m.g. each		Air and water	Filter surface		2½-24 hours	2½-24 hours	Venturi	41	9	63	0	
	Grand Rapids	12.35	Grand River	Alkalinity and total hardness as low as possible	No	10	Rapid sand	2 m.g.a.d.	21 hours	High velocity water	Before filters	Automatic	2-4 hours	6-8 hours	Venturi	16-68 33	3-23 7	3-126 13	0	Trace
Minnesota	Minneapolis	30.0	Mississippi River	Below 10 bacteria per cubic centimeter; B. coli absent in 20 cc.	Yes	16	Mechanical concrete	72 m.g.a.d.	24 hours	Water	After filtration	Automatic	3-6 hours	36 hours	Venturi	21-84 41	9-27 12	1-150 18	0	0.11-0.6 0.33
Missouri	St. Louis	98.0	Mississippi River	Agar count below 50; B. coli absent in 50 cc.	Yes	40	Rapid sand	60-100 m.g.a.d. 85 m.g.a.d.	3-168 hours 48 hours	Water	After filtration	For alum Nor for iron and lime	30-40 hours 5-6 hours	1 day	Venturi	12-80 35	9-18 11	25-4800 1500	0 0	
	Springfield	4.0	Springs and deep wells	Bacteria as low as possible; no B. coli	Yes	6	Gravity	2 gal. sq. ft. min.	24 hours	Air and water	Part in raw; part in filtered	Automatic	3 hours	2 hours	Venturi	3-6 3.5	0	0-315 10.8	0	
Nebraska	Omaha	20.0	Missouri River	Count less than 100; no B. coli in 1 cc.	No	None					Suction well	Manual	48-72 hours	48 hours	Venturi	6-10	0-10	50-1300	0-5	
New Jersey	Paterson, etc.	37.0	Passaic River	Color 10 or less; bacteria 5	No	32	N. Y. C. J.	120-200 m.g.d.	11.50 hours	Air and water	Effluent from filters		4.14 hours	10 days	Venturi	32	9	7	0	0.1
	Trenton	17.5	Delaware River	Bacteria reduction 99.9 per cent; B. coli negative 90 per cent	Yes	16	Rapid sand	1.5-2 gal. sq. ft. min.	12-100 hours	Air and water	Effluent		2½-5 hours	1 week	Pitometer	10-80	3-15	2-3000	0-3	
New York	Albany	20.0	Hudson River	Gelatin count under 50; agar count under 5	Yes	16 8	Rapid sand Slow sand	80 m.g.a.d. 3.5 m.g.a.d.	24 hours 1 month	Water, scraping	Effluent		12-14 hours	1 hour	Venturi	41	23	2.3	0	0.2
	Auburn	6.5	Owasco Lake	Less than 25 per cent B. coli tests positive Gelatin 100; color 10	No						Suction well	Automatic								
	Kingston	4.5	Sawkill Creek	Gelatin 100; color 10; turbidity 0.	Yes	12	N. Y. C. J. pressure		24 hours	Water	Effluent of filters	Automatic	None	None	Venturi	5-65 20	0-10 4	1-50 20	0	
	Mt. Vernon	2.5	River	Below 50 bacteria per cubic centimeter	Yes	4	American Pipe and Construction Co.	100 per cent capacity	24 hours	Water	Intake	Automatic	5 hours	None	Simplex			10-300		
	Newburgh	5.13	Lake	Free from gas-formers in 10 cc.	Yes											20	20	0	0	0.05
	New York	550.0	Surface and ground supplies	Free from B. coli in 10 cc.										Varies	Venturi	13-27 18	8-23 14	1-5 2	1-6 2	0-0.5 0.2
	Niagara	10.5	Niagara River	Free from B. coli in 10 cc.		16	Rapid	½-1½ m.g.d.	24 hours	Air and water	Effluent from filters		4 hours	2 hours		Trace	Trace.	10-3000		
	Poughkeepsie	2.54	Hudson River	100 per cent	Yes	4	Slow sand	2½ m.g.a.d.	93 days	Ejector system	Raw and filtered		20 hours	3-5 days	Venturi	25-70 40.6	0-35 9.2	12-500 52.5	0	
	Schenectady	11.16	Three dug wells																	
	Syracuse		Skaneatles Lake	B. coli absent																
	Utica	12.5	West Canada Creek		Yes						At Venturi from reservoir	Automatic								
	Watertown	5.5	Black River	Color below 10; count 20	Yes	8	Rapid sand	120 m.g.a.d.	6-48 hours	Water	Effluent from reservoir		3 hours	1 day	Venturi	40-140	0-30	2-10	0.6	0.2-0.4
	Yonkers	9.0	Nepperhan River, Grassy Sprain Creek	Bacteria 15 to 25 per cubic centimeter; no. B. coli in 10 cc.	Yes	2 4	Open slow sand Closed slow sand	3-5 m.g.a.d.	3-6 weeks	Scraping	Effluent from reservoir			1 hour or less	Venturi	22	13	5.2	0	
North Carolina	Wilmington	3.0	Cape Fear River	B. coli absent in 10 cc.	Yes	8	Mechanical	100-135 m.g.a.d.	17-90 hours	Air and water	Clear well		6 hours			60-300	0-30	10-1000	0-30	Trace
Ohio	Akron	20.0	Cuyahoga River	Free from B. coli in 1 cc.; usually in 10. 20° Count < 100	No	10		125 m.g.a.d.		Water, 21 inch rise	Suction well		24 hours	20 m.g. basin	Venturi	33	12	11	0	0.43
	Alliance	6.0	Mahoning River	Turbidity 0; no B. coli in 1 cc.	Very	6		125 m.g.a.d.	2-54 hours 20 hours	Water, 24 inch rise	Effluent from filters		3 hours	20 minutes	Revolution counter	20-40 25	3-20 12	5-1400 35	0	0.5-3.5 1.0
	Bucyrus	1.5	Reservoir		Yes	4	2 Pittsburgh mechanical 2 tub and rake	Nearly full capacity	24 hours	Air and water	Before filtration		6 hours	4 hours		Yellow	Clear blue	90	10	
	Cincinnati	50.0+	Ohio River		Yes	28	4 m.g. mechanical	125 m.g.a.d.	20 hours	High velocity washing	Effluent from filters		6-12 hours	6-12 hours		5-25 10	3-12 7	3-4000 185	0-tr.	0.01-0.4 0.05
	Cleveland	96.0	Lake Erie	As low as possible in bacteria without producing bad taste and odor of chlorine	No		Rapid sand				Pump suction	Automatic	3 hours	<4 hours	Venturi (raw)	<10		15		Very lo
	Columbus	20.0	Scioto River	B. coli absent in 50 cc.; total count below 20	Yes	10	Mechanical	110 m.g.a.d.	48 hours	Water	As applied to filters	Automatic	18 hours	12 hours	Venturi	29	4	58	0	
	Dayton	12.9	Deep wells	B. coli absent in 10 cc.	No										Venturi and pitometer			0		0.15
	Dennison	2.0	Big Stillwater Creek	B. coli absent in 10 cc.; not over 20 bacteria at 20°	Yes	4	16 foot Jewell	125 m.g.a.d.	When needed	Water	Clear well		4 hours	None	Venturi	"Mud"	Clearer	50-1900	30-100	
	Lima	3.5	Ottawa River	Free from B. coli	Yes		Mechanical				Pump suction	Automatic			Revolution counter	20		20		0.1-1
	Niles	1.5	Mahoning River	B. coli absent in 10 cc.; less than 50 bacteria	Yes	4	300 square foot area; mechanical	1 gal. sq. ft. min.	24 hours	Water		Automatic	24 hours	2.5 m.g.		23	0	40-1000	0	0-4
	Port Clinton	0.56	Lake Erie	Normal carbonate alkalinity 3 to 6 p.p.m.	Yes	3	Mechanical	Normal	48-60 hours	Air and water			½-2 hours	2.5 m.g.		10	0	0-600	0	16
	Sandusky	4.5	Sandusky Bay	Less than 50 bacteria; no B. coli; turbidity color < 10	Yes	10	Mechanical gravity	125 m.g.a.d.	24 hours	Air and water	Immediately before filters	Automatic	15 hours	15 hours	Revolution counter	4-36	4-10	10-3500	0	2
	Steubenville	4.2	Ohio River	No free CO_2; bicarbonate alkalinity 8 to 9 p.p.m.	Sometimes	6	Norwood Engineering Co.	90-121 m.g.a.d.	50 hours	Air and water	Immediately before filters	Automatic	5 hours	12 hours at plant 24 hours down town		0	0	5-300	0	
	Toledo	21.8	Maumee River	3 parts free CO_2 when using alum; 4 parts monocarbonate alkalinity when using Fe and lime	Yes	34	Norwood Engineering Co.	1 m.g.d.	24 hours	Air and water	Filter effluent		3 hours	20 hours	Venturi	10-140 45	5-45 13	15-2500 164	0	0.1
Oregon	Portland	65.0	Bull Run Lake		No											Clear		Clear		
Pennsylvania	Allentown	12.0	Two springs	No B. coli in 100 cc.	Yes						Clear well	Automatic				0	0	0	0	0
	Erie	19.0	Lake Erie	Sterile; no turbidity. Color < 5.	Yes	12	Rapid sand		24 hours	Mechanical washing	Filter effluent	Automatic	3.5 hours	1.5 days	Venturi	0-30	<5	2-110	0	
	Lancaster	7.23	Conestoga Creek	Less than 50	Yes	15	Maignon design	10 m.g.a.d.	When necessary	Back flush and raking sand	Filter effluent		1 hour	1 day	Venturi	10-35	10	10-9000	0-3	
	McKeesport	5.0	Youghiogheny and Monongahela	No B. coli in 10 cc.; turbidity 0; hardness < 80	Yes	6	Rapid sand, 1 m. units	113 m.g.a.d.	72 hours	Air and water		Automatic	6-12 hours	24 hours	Venturi	Y-0-30 M-0-200	0-70 Trace	0-16,000 50	0	0.5
	Philadelphia	300.0	Delaware and Schuylkill Rivers	Free from B. coli in 1 and 10 cc.	Yes	118 189	Slow sand Rapid sand	6 m.g.a.d.	77 days	Hand scraping	Filtered water basin									
	Reading		Reservoirs and springs			21	Slow sand													
Rhode Island	Newport	6.5	Impounded surface	Maxima bacteria 10; color 10; alkalinity 6 to 7; turbidity 0	Not very	6	Rapid sand	1½ m.g. per unit	12-24 hours	Air and water	Filter effluent	Automatic	3½ hours		Venturi	36-46	6-10	5-10	0	
	Providence	22.5	Pawtucket river		Yes	10	Slow sand, 1 acre	2-4.5 m.g.a.d.	17 times a year	Hand scraping					Venturi	30-70 48	17-40 33	0	0	
South Carolina	Charleston	6.25	Improved reservoir	Color 15; alkalinity 20; hardness 50	No	12	N. Y. C. J.	½ m.g. per unit	24 hours	Water	Filtered water flume		40 hours	5 hours	Type "G" Simplex	130	18	3	0	
	Columbia	5.5	Congaree River	Count < 25; remove all B. coli type organisms	Yes	6	Mechanical gravity	125 m.g.a.d.	24 hours	Water	Filter effluent		2 hours	16 hours	Pitot tubes			60-1500	0-4	
South Dakota	Huron	0.5	James River	Count 10; no B. coli in 10 cc.		3	Mechanical gravity		24 hours	Air and water	Filter effluent		3 hours	<24 hours				300	1	
Tennessee	Nashville	13.0	Cumberland River	Bacteria < 50; no B. coli	Yes	None					After 3 days sedimentation		3-4 days	3-4 days	Revolution counter			100-3200	7	
Texas	Dallas	7.5			Yes	12	Mechanical	125 m.g.a.d.	24 hours	Air and water	Before filtration		4 days	6 days	Revolution counter		0	5-6500	0	
	Ft. Worth	5.0	Trinity River	U. S. T. D.	Yes	4	Gravity, rapid sand	125 m.g.a.d.	24 hours	Water	After filtration		3 hours	12 hours				400		
Virginia	Lynchburg	6.0	Reservoir on Pedlow River	U. S. T. D.	Yes	None					At reservoir outlet			24 hours		10-80	0-10	0-3000	0	
	Richmond	13.35	James River	Total count 10; no B. coli in 20 cc.; turbidity < 4	Yes											0		0-100		

TABLE 2

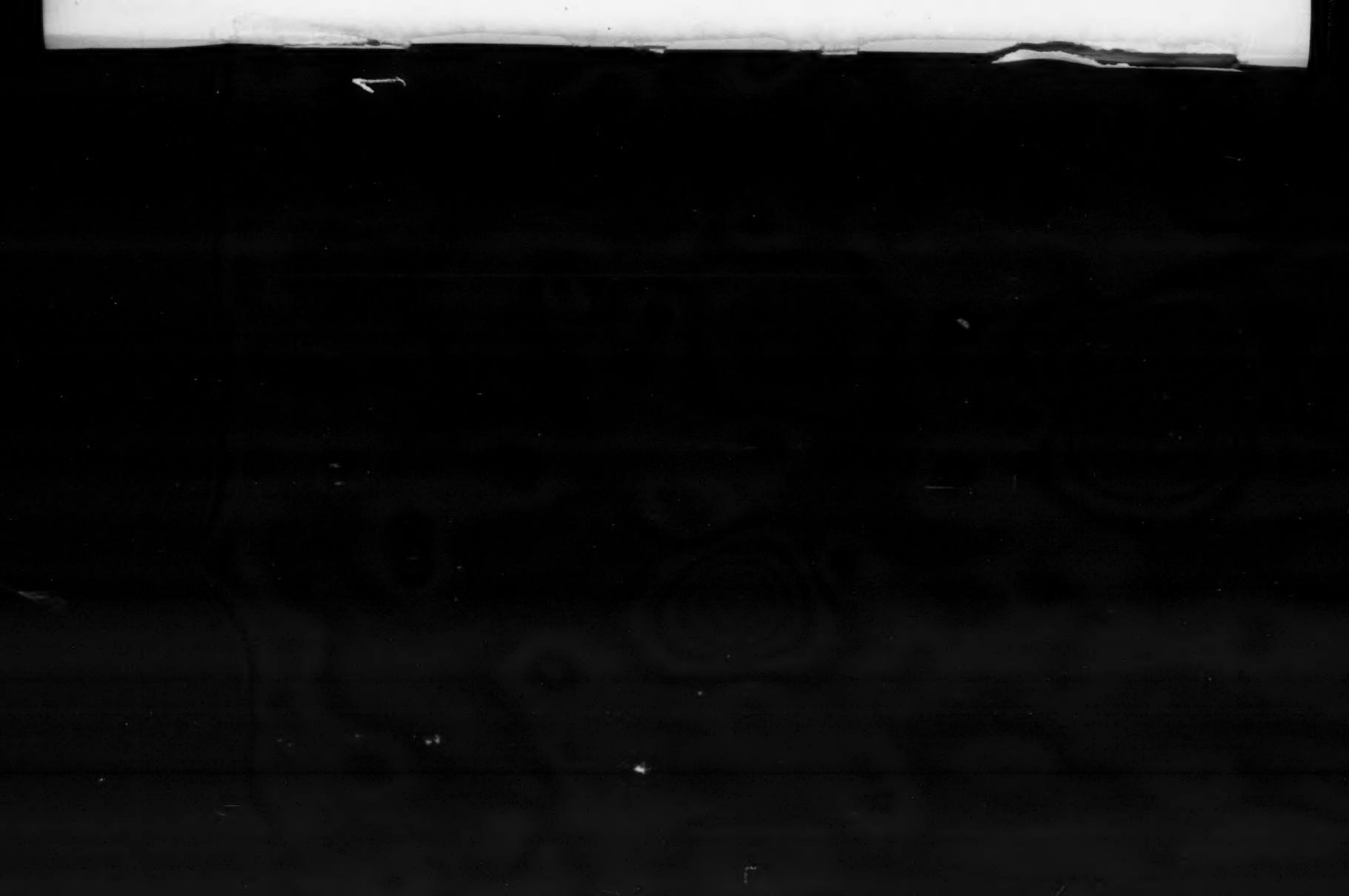
American Water Works Laboratories. (Plant Data)

How often cleaned	Manner of cleaning	Point of chlorination	Control of dosage of chemicals	Period of sedimentation	Storage of treated water	Consumption determined by	Color		Turbidity		Iron		Alkalinity		Bacteria at 37°C.		Bacteria at 20°C.		B. coli		Chemicals, pounds per million gallons							
							Raw	Ttd.	Raw	Ttd.	Raw	Ttd.	Raw	Ttd.	Raw	Treated	Raw	Ttd.	Raw	Ttd.	Aluminium sulphate	Copper sulphate	Iron sulphate	Lime CaO	Hydrated lime	Calcium hypochlorite	Liquid chlorine	Soda ash
		Intake	Manual		24 hours		15		5		<1		130		125				25 per cent 10 cc. samples							2.0–2.5	
		Intake	Manual		10 days	Venturi meter	Clear		No		2–6				0–200	0–10	5–800	0–15	None	None						1.7	
							No				3		Trace		17*		100*		1 per cent 1 cc.								
		After filtration	Automatic			Checked	2–50	0	2–400	0	0.2	0	90	85	1–280	0–17	1–5400	21–69								+	
		Where enters main					15		27																		
							28–48	20–36	1–8	Same			24–38	Same			617	19	15 per cent 10 cc.	Absent 10 cc.						5	
71 days	Scrape and rake			4 days	4 hours	Venturi	36	28	4																		
rs	Mechanical		Manual	6–10 hours	2 weeks	Venturi	Slight	No	238	0			58	55.4			5540	15	575.4 per 100 cc.	0.3	40		4				
								No	24–600	0			8–15	5–10	239	11					51						
hours	Air and water		Orifice tanks	6 hours	2½ m.g. basin		Red brown	Clear	10–3000				0–17		Max. 13,000	12			All times	1–2 per cent plus	71–355			35–130 when used			
30 hours	Air and water		Automatic	3 hours		Revolution counter		5		0		0	12	6	285	3				Negative	66						
en needed	Air and water	Effluent from filters		6 hours	15 hours	Venturi	Red	0	50–4000	0			2–30		50–200	0–2			Varies	None	100–213					2	71–284
hours	Back pressure	Between settling basin and main pump		6 hours	No	Manometer			8–3000	0			30–50	15–30			2000	10			200–800			6–10			
hours	Air and water	Effluent from filters	Manual	3 hours	1 hour	Revolution counter	10–30	0–5	100–3000	15–35	Very low	0	40–110	17–85	250–1500	5–40			Always present	97–98 per cent absent	71–568			Rarely	Rarely	2.6–3.3	
							0	0	0.120		0	0			11	6	Agar, 165 Gel. 210	Agar 55 Gel. 77	1.8 per cent in 1 cc.; 17.2 per cent in 10 cc.	0.2 per cent in 1 cc.; 10.8 per cent in 10 cc.					0.8–1.6	
hours	Air and water	Effluent from filters		1 hour	4–6 hours	Pitometer	20–250	0–30	25–2000	0	0.39	0	50–340		2230	0–15				12 per cent 10 cc. gas			15–850	23–690		1.0	
													250							0.15 per cent cc. confirmed			285	360			
ours	Water	Effluent from filters		4–6 hours	18 hours	Venturi on L. S.	0–20	0.10	10–285	0			188–274	180–270	52–7300	0–30	Gel. 6–75,000	0–340	Always present	Absent in 10 cc.	227*				4–8		
							12	3.7	139				237	224	1075	7	7203	49									
						Revolution counter	5–60		10–12		0.5–1		300		1–10		Gel. 2–3		Occasionally								
hours	Air and water	Effluent from filters		2 hours	4 hours	Recording Venturi	6	0	13	0			119	112	40	0.3	241	0.59	1.21	0	85				3		
0 hours	Air and water	Effluent from filters		2–3 hours	5 hours	Venturi	20–100	5	0–8000	0	Maximum 2		50–170	20–160	500–200,000	0–500					710–1275	8.3 when algae present		725 for few days		4.5–6.5	
hours	Air and water	Suction H. S. pump		4.5 hours	None	Venturi on both H. S. and L. S.	25–50	5–10	10–1500	0			82–186	42–154	34–50,500	0–585			22.9 per cubic centimeter	0.081 per cubic centimeter	355–1065					1.7–5.8	
							36.5	5.6	110				134	109	2085	10.9					470						
ours	Water	Effluent from filters		5.5 hours	1.2 hours	Revolution counter	10–120	0.1–20	10–3000	0			10–290		100–300,000	0–110					0–900		0–800		8–16	1.5–6	
ours	Air and water	Coagulated water	Manual	5 hours	3 hours	Venturi	8–12	5	15–4000	0	Traces		35–115		1250	50	Gel. 5000	45	78.1 per cent of 1/10 cc.	5.8 per cent of 1 cc. 17.3 per cent of 10 cc.			350		170	7		
							Clear		Slight at times				30–35		1–3				None								
0 days	Scrape, washing	Effluent from filters	Manual	48 hours	12 hours	Venturi	10–480	5–35	3–338	0–3	0.9–3	0.1–0.7	188–259	81–258	255–3500	0–20	180–15,000	0–150	1173 per 100 cc.	0.64 per 100 cc.	Variable				50–750		1–2.5	
							53	12	39	0	1.9	0.26	237	238		5	1722	9									
ours	Water			4 hours	None	Tachometer	34	14	138	0	Small		195	185			Gel. 3200	38			280						
3 hours	Air and water	Clear well		2½–3 hours	½–1 hour	Revolution counter	36–58	20–45			No	Trace	230–580	140–460	50–640	0–58	Gel. 80–1800	0–140	Present in summer	5 per cent of 1 cc. 20 per cent of 10 cc.	185					2.73	
													300	220	220	18	360	39									
ours	Air and water	Effluent from filters		½–1 hour	3 hours (maximum)	Revolution counter	0–100	0–10	0–3000	0	0.3	0.3	50–250	20–240	100–50,000	0–100	Gel. 1000–1,000,000	0–1000	1–1000 per cubic centimeter	Less than one	21–285	8.3			10–15	2.1–4.2	
									90				200	190													
		After sedimentation		5–6 days	None	Pitometer	0–80	0–60	50–12000	0–50	0.2–0.5			100–250			5000–150,000	5–200			140–425	8.3			71–210	1.7–2.5	
							15	10	2500	4				150			24,000	48			210	In summer			125	2–1	
ours	Air and water	After coagulation		24 hours		Revolution counter	30–80	3–30	3–3000	0–15			71–174	32–165			Gel. 5890	18			521					4.5	
		Effluent gallery	Automatic			Venturi	Trace	None	15	3	0.6	0.6	243	243	80	7	535	43	44.5 per cent of 5 cc.	3 per cent of 1 cc. 7.4 per cent of 5 cc. 7.4 per cent of 10 cc.						3.5	
			Automatic	1 week	1 week	Revolution counter			400+	5–15											152				142	10–12	
ours	Water	After coagulation	Manual	4.8 or 12 hours	24 hours	Revolution counter	0	0	Maximum 600 Average 400	0	2–20 7	0.1–2.0 1	30–80 55	15–70 45	L. L. A. 2000	5	Gel. 25,000	50	100 per cubic centimeter	1 per 300 cc.	142				7.5	1.8	
hours	Air and water			6 hours	6 hours	Revolution counter	10–100	5–50	70–800	0			70–130	60–120	2000–70,000	0–400			Variable		11–570						
days; 106 rs	Water	Effluent from filters	Automatic	12 hours	None	Venturi	8–20 10	3–6 5	60–2400 600	0–3 0	0.3 0.05	Trace	53–175 94	25–75 37	400–9500 200 L. L. A. 2	1–120 14	Gel. 500–7500 2900	2–550 38	35 per cent 1 cc. None	5 per cent of 10 cc.			0–170 62.5	440–1150 770		1.76–7.92 4.39	0.83–1.3 1.19	
weekly 40 days	Water Scraping	None used		2 hours	4 hours	Venturi	38	0	25	0	2.25 Minimum 1.9	0.2 0.00	23														
	Air and water	Filter surface		2½–24 hours	2½–24 hours	Venturi	41	9	63	0			212	204	357	2	1220	5	318 days in 1 cc.	1 day in 1 cc.	253.2					2.9	
rs	High velocity water	Before filters	Automatic	3–4 hours	6–8 hours	Venturi	16–68 33	3–23 7	3–126 13	0	Trace		103–351 200	32–123 53	80	3	1340	4	5.700 in 1 cc.	0.00672 in 1 cc.	132			1290		6		
rs	Water	After filtration	Automatic	3–6 hours	36 hours	Venturi	21–84 41	9–27 12	1–150 18	0	0.11–0.66 0.33	0.03–.07 0.05	77–202 153	52–190 134	775	7	2250	24	15 per cubic centimeter	0.2 per 100 cc.	346					2.5	
hours rs	Water	After filtration	For alum Nor for iron and lime	30–40 hours 5–6 hours	1 day	Venturi	12–80 35	9–18 11	25–4800 1500	0 0		0.005	74–258 142	26–111 52	300–79,000 12,000	2–135 16	11,000–500,000 81,000	26–1070 170	0–265 31	0.0024–0.0425 0.0166	0–234 85		0–355 94	430–862 743		0–4 1.45		
rs	Air and water	Part in raw; part in filtered	Automatic	3 hours	2 hours	Venturi	3–6 3.5	0	0–315 10.8	0			134–197 165				Gel. 1436	6	36.42 per cent of 1 cc.	0	61				6.4		
		Suction well	Manual	48–72 hours	48 hours	Venturi	6–10	0–10	50–1200	0–5			96–260	80–260		30	Gel. 20,000 Agar, 12,000	60 50	98 per cent of 1 cc.	0	177			142		2.5	
ours	Air and water	Effluent from filters		4.14 hours	10 days	Venturi	32	9	7	0	0.1	0	18–32 26	20					65 per cent positive		155				14.5	1.7	8.3
hours	Air and water	Effluent		2½–5 hours	1 week	Pitometer	10–80	3–15	2–2000	0–3			5–40	5–30			10,000	6	98 per cent of 1 cc.	5 per cent of 10 cc.	81–109					1.7	
rs ath	Water, scraping	Effluent		12–14 hours	1 hour	Venturi	41	23	2.3	0	0.2	0.2	68	66	Neutral bile agar, 135 Agar, 975 5–50	9 3	Gel. 51,525 Gel. 10–80	22	45 11.3 per cent of 10 cc.	0	308					4.0	
rs	Water	Effluent of filters	Automatic	None	None	Venturi	5–65 20	0–10 4	1–50 20	0			8–19 12	7.5–19 11	850	0–50 8	Gel. 17,500	0–40 10	0/5–5/5, Av. 2/5	0/5	35–71	2–3			4.7		
ys	Water	Intake	Automatic	5 hours	None	Simplex			10–200			0.2	15–80	15–60			1000	20	Present	Rarely in 10 cc.; never in 1 cc.	50–100					2.5–3.5	
							20	20	0	0	0.05	0.05	32	33	480	38			Present in 1 cc.	Absent in 10 cc.		2.5				1.5–3.75	
					Varies	Venturi	13–27 18	8–23 14	1–5 2	1–6 2	0–0.5 0.2	0.1–0.2 0.16	19–36 28	28–32 31	3–500 62	2–480 18			3 per cent of 1/10 cc.: 11 per cent of 1 cc.; 40 per cent of 10 cc.	2 per cent of 1 cc.; 19 per cent of 10 cc.							
s	Air and water Ejector system	Effluent from filters Raw and filtered		4 hours 30 hours	2 hours 3–5 days	Venturi	Trace 25–70 40.6	Trace 0–35 9.2	10–2000 12–600 52.5	0			101 30–57 44.3	90 24–56 37.7	1,001	0–10 3	600–50,000 Gel. 5509 Gel. 3	0–50 0–14 4	75 per cent of 1/10 cc. +	15 per cent 10 cc. 0.24 per cent 1 cc.; 1.44 per cent 10 cc. Absent	85				4.75		
		At Venturi from reservoir	Automatic																	Absent							
rs	Water	Effluent from reservoir		3 hours	1 day	Venturi	40–140	0–50	2–10	0.6	0.2–0.4	0–0.2	14.1 10–35	4.20	110	12	Gel. 200–50,000	0–1500 20	11.5 per cent	1.5 per cent	200–450					1.7–3.3	
ks	Scraping	Effluent from reservoir			1 hour or less	Venturi	22	13	5.2	0			8	8.7			Gel. 300–31,000	21	91.8 per cent of 1 cc.						12–20	2–3	
urs	Air and water	Clear well		6 hours			60–300	0–30	10–1000	0–30	Trace		5–9	10	400	8	1476	19	7 per cubic centimeter	4 per 1000 cc.	327				140	3.3	
	Water, 21 inch rise	Suction well		24 hours	20 m.g. basin	Venturi	33	12	11	0	0.43	0.05	70	58	246	11	1827	34	Index 1.295	0.009	214					1.89	
rs	Water, 24 inch rise	Effluent from filters		3 hours	20 minutes	Revolution counter	20–40 25	3–20 12	5–1400 35	0	0.5–3.5 1.0	0–0.1 0.02	12–210 130	5–205 120	1500 (acid formers 520)	40 Acid formers rare	5000	80	Always in 1 cc.	33 per cent of 10 cc. Rarely in 1 cc.	17–640 157					2.5–4.1 3.7	
	Air and water	Before filtration		6 hours	4 hours		Yellow	Clear blue	90	10			50–80	20–40							200–800				16		
	High velocity washing	Effluent from filters		6–12 hours	6–12 hours		5–25 10	3–12 7	3–4000 185	0–tr.	0.01–0.05 0.03	0.01–.10 0.05	22–62 35	33–60 41			100–310,000 13,900	2–480 48	0.1–1000 21.56 per cubic centimeter	0–1 0.07198 per cubic centimeter			106–355 187	64–142 106		0.9–1.5 1.1	
		Pump suction	Automatic	3 hours	<4 hours	Venturi (raw)	<10		15		Very low		90		106	19									5–12		
	Water	As applied to filters	Automatic	18 hours	12 hours	Venturi	29	4	58	0			170	51			8027*	24*	44 per cubic centimeter* 1/13 in 10 cc.	0.084 per cubic centimeter	284			1206		5		782
						Venturi and pitometer			0		0.15		282		0–9		3–7										
ded	Water	Clear well		4 hours	None	Venturi	"Mud"	Clearer	50–1900	20–100			90±	80±	9000	6000	40,000	27,000			0–or 71–284		142–568	25		8		
		Pump suction	Automatic			Revolution counter	20		20		0.1–1.0		100–200				720	60	Present	Absent						8	1.8	
	Water		Automatic	24 hours	2.5 m.g.		23	0	40–1000	0	0–8	0	20–150		200–210,000	0–180	2000–100,000	0–500	Up to 400 per cubic centimeter							4.1–6.2	
rs	Air and water			½–2 hours	2.5 m.g.																						
	Air and water	Immediately before filters	Automatic	15 hours	15 hours	Revolution counter	10	0	0–600	0	16.4	0.4	82–124	50–90	1050‡	0‡	1540‡	0‡	Present	Absent			300		370			
	Air and water	Immediately before filters	Automatic	5 hours	12 hours at plant 24 hours down town		4–36	4–10	10–3500	0	2.0	0.5–1.0	85–120	70–105			500–350,000	0–120	95 per cent of 1 cc.	1/10 per cent of 1 cc.					7.5		
							0	0	5–300	0		<0.2		20–30	10–70,000	2	100–500,000	4	20	0			0–295		85–355	3–6.2		
	Air and water	Filter effluent		3 hours	20 hours	Venturi	10–140 45	5–45 13	15–2500 164	0	0.1–3.5 1.5	Tr.–0.15 0.1	66–241 156	27–156 63			200–318,500 22,002	1–260 34	Index 23.42	Index 0.011	152		238		667	6.2		
		Clear well	Automatic				Clear		Clear		0.8				4				0								
	Mechanical washing	Filter effluent	Automatic	3–5 hours	1.5 days	Venturi	0	0	0	0	0.1		120		<200	<25	<500	<50	50 per cent of 10 cc.	None in 100 cc.						0.8	
ssary	Back flush and raking sand	Filter effluent		1 hour	1 day	Venturi	0–30	<5	2–110	0			100	98–99	40–200	0–4	200–6000	0–40	30 per cent of samples	0	28					3.5		
	Air and water		Automatic	6–12 hours	24 hours	Venturi	10–35	10	10–9000	0–3	1		80–140				Gel. 7000	38	Present in 1 cc.		353					1.5		
							Y–0–30 M–0–200	0–70 Trace	0–16,000 50	0	0.5–9.0 1.2	0–6 0.3	Acid 40–90 60	15–50 30	1400	7	3000	40	Y–35 per cent of 1 cc. M–70 per cent of 1 cc.	19 times in 10 cc. in 16 years				100–3800 866			0–1450 700
	Hand scraping	Filtered water basin																								1.2	
	Air and water	Filter effluent	Automatic	3½ hours		Venturi			32.8	0.09							Gel. 2167	48									
						Venturi	36–46	6–10	5–10	0			10–25	6–20	200–1500	0–10	200–5000	0–10	0.0–0.5 per cubic centimeter	0	71–213	1–10 when used				2.5–5.0		14–35
ear	Hand scraping					Venturi	30–70	17–40	0	0			6–16	6–15	100–25,000	1–150			Present in 1/100 cc.	Frequent in 10 cc.; seldom 1 cc.							
	Water	Filtered water flume		40 hours	8 hours		48	33					10.6	10	1300	10											
	Water	Filter effluent		2 hours	16 hours	Type "G" Simplex Pitot tubes	130	18	3	0	1.0	0.05	12	20	650	80			0	0	284				94	16		
									60–1500	0–4			6–22 12		300–2000	15					220						
	Air and water	Filter effluent		3 hours	<24 hours				300	1					500	5–10			Present in 5 cc. in winter Present in 1/10 cc. in summer	0 in 10 cc.	625					5.0	
		After 3 days sedimentation		3–4 days	3–4 days	Revolution counter			100–3200	7					2500–3500	24–70			Practically always		142–426					7.1	
	Air and water	Before filtration		4 days	4 days	Revolution																					

	Elgin	1.60	Five wells, 42-200		No		N. Y.																
	Evanston	8.50	Lake Michigan	Very few bacteria. No gas. No color, turbidity, alum, free chlorine	Yes	6	2 m.g. gravity mechanical	100-125 m.g.a. d.	8-48 hours	Air and water	Effluent from filters		2 hours	4 hours	Revolution counter	5-60		10-12					
	Moline	4.00	Mississippi River	Bacteria, 0; gas absent in 1 cc. and 4/5 10 cc.; color 15; turbidity, 0	Yes	5	Concrete gravity	125 m.g.a.d.	12-40 hours	Air and water	Effluent from filters		2-3 hours	5 hours	Recording Venturi	6	0	13	0				
	Quincy	2.00	Mississippi River	Agar count below 50; Coli absent in 10 cc.	Yes	6	N. Y. C. J., 1 m.g. units	120 m.g.a.d.	4-20 hours	Air and water	Suction H. S. pump		4.5 hours	None	Venturi	20-100	5	0-6000	0				
	Streator		Vermillion River	Below 50 bacteria in 1 cc., negative gas tests	Very	16	American pressure	1½ feet per minute	24 hours	Water	Effluent from filters		5.5 hours	1.2 hours	Venturi on both H. S. and L. S.	25-50	5-10	10-1500	0				
	Evansville	9.0	Ohio River	U. S. T. D.	Yes	12	Gravity	125 m.g.a. d.	24 hours	Air and water	Coagulated water	Manual	5 hours	3 hours	Revolution counter	10-120	0.1-20	10-3000	0				
	Fort Wayne	6.0	Deep wells		No										Venturi	8-12	5	15-4000	0				
Indiana	Indianapolis	24.31	Surface and deep wells	U. S. T. D.	Yes	6	Slow sand	4-6 m.g.a.d.	25-30 days	Scrape, washing	Effluent from filters	Manual	48 hours	12 hours	Venturi	10-480	5-35	3-338	0-3				
	Terre Haute	5.0	Wabash River	Bright and clear	Yes	22	Jewell pressure	90 m.g.a.d.	24 hours	Water			4 hours	None	Tachometer	33	12	39	0				
	Valparaiso	0.8	Chain of small lakes	U. S. T. D.	Seldom	3	Gravity	50 m.g.a.d.	24-36 hours	Air and water	Clear well		2½-3 hours	4-1 hour	Revolution counter	34	14	138	0				
	Cedar Rapids	3.0	Cedar River and 1500 feet wells	U. S. T. D.	Yes	14	12 Tub Jewell; 2 N. Y. C. J.	75 m.g.a.d.	24 hours	Air and water	Effluent from filters		½-1 hour	3 hours (maximum)	Revolution counter	36-58	30-45						
	Council Bluffs	3.25	Missouri River	Less than 50 bacteria per cubic centimeters. No gas formers		None					After sedimentation		5-6 days	None	Revolution counter	0-100	0-10	0-3000	0				
Iowa	Davenport	4.14	Mississippi River	As nearly sterile as possible	Yes	12	Pressure	1 gal sq. ft. min.	24 hours	Air and water	After coagulation		24 hours		Pitometer	0-80	0-60	90					
	Des Moines	6.9	Infiltration gallery, Raccoon Valley	75 bacteria per cubic centimeter; no gas formers	Yes.	None					Effluent gallery	Automatic			Revolution counter	15	10	50-12000	0-50				
Kansas	Atchison	1.2	Missouri River		Yes										Venturi	30-60	3-30	2500	4				
Kentucky	Louisville	26.0	Ohio River	Less than 100 bacteria; no B. coli in 1 and 10 cc.	Yes	18	Gravity	130 m.g.a.d.	20 hours	Water	After coagulation	Automatic	1 week	1 week	Revolution counter	Trace	None	3-3000	0-15				
	Morgan City	0.25	Atchafaloya River	No B. coli; 98 to 100 per cent bacteria removal	No	2	Rapid sand	5,000 gallons per hour	24-48 hours	Air and water		Manual	4.8 or 12 hours	24 hours	Revolution counter			15	3				
Louisiana	New Orleans	30.0	Mississippi River	U. S. T. D.	No	10	Rapid sand	40-150 m.g.a.d.	2-12 days; 106 hours	Water	Effluent from filters							400+	5-15				
Massachusetts	Brockton	2.9	Silver Lake	Do not treat									6 hours	6 hours	Revolution counter	0	0	Maximum 600 Average 400	0				
	Lowell	6.0	2½ feet driven wells	Remove Fe and Mn. (plant for that purpose)	No	12	6 Coke prefilters 6 Slow sand	Coke—75 m.g.a.d. Sand—10 m.g.a.d.	Coke weekly Sand 40 days	Water Scraping	None used		2 hours	4 hours	Venturi	38	0	25	0				
Michigan	Bay City	7.0	Saginaw River and Bay																				
	Dearborn	0.10	River Rouge	As near 0 bacteria as possible	Yes	4	N. Y. C. J., gravity	½ m.g. each		Air and water	Filter surface		2½-24 hours	2½-24 hours	Venturi	41	9	63	0				
	Grand Rapids	12.35	Grand River	Alkalinity and total hardness as low as possible	No	10	Rapid sand	2 m.g.a.d.	21 hours	High velocity water	Before filters	Automatic	2-4 hours	6-8 hours	Venturi	16-68	3-23	3-126	0				
Minnesota	Minneapolis	30.0	Mississippi River	Below 10 bacteria per cubic centimeter; B. coli absent in 20 cc.	Yes	16	Mechanical concrete	72 m.g.a.d.	24 hours	Water	After filtration	Automatic	3-6 hours	36 hours	Venturi	33	7	13					
	St. Louis	98.0	Mississippi River	Agar count below 50; B. coli absent in 50 cc.	Yes	40	Rapid sand	60-100 m.g.a.d. 85 m.g.a.d.	3-168 hours 48 hours	Water	After filtration	For alum Nor for iron and lime	30-40 hours 5-6 hours	1 day	Venturi	21-84 41	9-27 12	1-150 18	0				
Missouri	Springfield	4.0	Springs and deep wells	Bacteria as low as possible; no B. coli	Yes	6	Gravity	2 gal. sq. ft. min.	24 hours	Air and water	Part in raw; part in filtered	Automatic	3 hours	2 hours	Venturi	12-80 35	9-18 11	25-4800 1500	0 0				
Nebraska	Omaha	20.0	Missouri River	Count less than 100; no B. coli in 1 cc.	No	None					Suction well	Manual	48-72 hours	48 hours	Venturi	3-6 3.5	0	0-315 10.8	0				
New Jersey	Paterson, etc.	37.0	Passaic River	Color 10 or less; bacteria 5	No	32	N. Y. C. J.	120-200 m.g.d.	11.50 hours	Air and water	Effluent from filters		4.14 hours	10 days	Venturi	6-10	0-10	50-1200	0-5				
	Trenton	17.5	Delaware River	Bacteria reduction 99.9 per cent; B. coli negative 90 per cent	Yes	16	Rapid sand	1.5-2 gal. sq. ft. min.	12-100 hours	Air and water	Effluent		2½-5 hours	1 week	Pitometer	32	9	7	0				
New York	Albany	20.0	Hudson River	Gelatin count under 50; agar count under 5	Yes	16	Rapid sand	80 m.g.a.d.	24 hours	Water, scraping	Effluent		12-14 hours	1 hour	Venturi	10-80	3-15	2-3000	0-3				
				Less than 25 per cent B. coli tests positive		8	Slow sand	3.5 m.g.a.d.	1 month							41	23	2.3	0				
	Auburn	6.5	Owasco Lake	Gelatin 100; color 10	No						Suction well	Automatic											
	Kingston	4.5	Sawkill Creek	Gelatin 100; color 10; turbidity 0.	Yes	12	N. Y. C. J. presure		24 hours	Water	Effluent of filters	Automatic	None	None	Venturi	5-65	0-10	1-50	0				
	Mt. Vernon	2.5	River	Below 50 bacteria per cubic centimeter	Yes	4	American Pipe and Construction Co.	100 per cent capacity	24 hours	Water	Intake	Automatic	5 hours	None	Simplex	20	4	20					
	Newburgh	5.13	Lake	Free from gas-formers in 10 cc.	Yes											20	20	10-200					
	New York	550.0	Surface and ground supplies	Free from B. coli in 10 cc.										Varies	Venturi	13-27	8-23	0	0				
	Niagara	10.5	Niagara River	Free from B. coli in 10 cc.		16	Rapid	1-1½ m.g.d.	24 hours	Air and water	Effluent from filters		4 hours	2 hours		18	14	1-5	1-6				
	Poughkeepsie	2.54	Hudson River	100 per cent	Yes	4	Slow sand	2½ m.g.a.d.	93 days	Ejector system	Raw and filtered		20 hours	3-5 days	Venturi	Trace	Trace	2	2				
	Schenectady	11.16	Three dug wells													25-70	0-35	10-3000					
	Syracuse		Skaneatles Lake	B. coli absent												40.6	9.2	12-600	0				
	Utica	12.5	West Canada Creek		Yes						At Venturi from reservoir	Automatic						52.5					
	Watertown	5.5	Black River	Color below 10; count 20	Yes	8	Rapid sand	120 m.g.a.d.	6-48 hours	Water	Effluent from reservoir		3 hours	1 day	Venturi	40-140	0-50	2-10	0.6				
	Yonkers	9.0	Nepperhar River, Grassy Sprain Creek	Bacteria 15 to 25 per cubic centimeter; no. B. coli in 10 cc.	Yes	2	Open slow sand	3-5 m.g.a.d.	3-6 weeks	Scraping	Effluent from reservoir			1 hour or less	Venturi	22	13	5.2	0				
						4	Closed slow sand																
North Carolina	Wilmington	3.0	Cape Fear River	B. coli absent in 10 cc.	Yes	8	Mechanical	100-135 m.g.a.d.	17-90 hours	Air and water	Clear well		6 hours			60-300	0-30	10-1000	0-30				
Ohio	Akron	20.0	Cuyahoga River	Free from B. coli in 1 cc.; unusally in 10. 20° Count < 100	No	10		125 m.g.a.d.		Water, 21 inch rise	Suction well		34 hours	20 m.g. basin	Venturi	33	12	11	0				
	Alliance	6.0	Mahoning River	Turbidity 0; no B. coli in 1 cc.	Very	6		125 m.g.a.d.	2-54 hours 20 hours	Water, 24 inch rise	Effluent from filters		3 hours	20 minutes	Revolution counter	30-40 25	3-20 12	5-4000 35	0				
	Bucyrus	1.5	Reservoir		Yes	4	2 Pittsburgh mechanical 2 tub and rake	Nearly full capacity	24 hours	Air and water	Before filtration		6 hours	4 hours		Yellow	Clear blue	90	10				
	Cincinnati	50.0+	Ohio River		Yes	28	4 m.g. mechanical	125 m.g.a.d.	20 hours	High velocity washing	Effluent from filters		6-12 hours	6-12 hours		5-25	3-12	3-4000	0-tr.				
	Cleveland	96.0	Lake Erie	As low as possible in bacteria without producing bad taste and odor of chlorine	No		Rapid sand				Pump suction	Automatic	3 hours	<4 hours	Venturi (raw)	10 <10	7	135 15					
	Columbus	20.0	Scioto River	B. coli absent in 50 cc.; total count below 20	Yes	10	Mechanical	110 m.g.a.d.	48 hours	Water	As applied to filters	Automatic	18 hours	12 hours	Venturi	29	4	58	0				
	Dayton	12.9	Deep wells	B. coli absent in 10 cc.	No										Venturi and pitometer			0					
	Dennison	2.0	Big Stillwater Creek	B. coli absent in 10 cc.; not over 20 bacteria at 20°	Yes	4	16 foot Jewell	125 m.g.a.d.	When needed	Water	Clear well		4 hours	None	Venturi	"Mud"	Clearer	50-1900	20-100				
	Lima	3.5	Ottawa River	Free from B. coli	Yes		Mechanical				Pump suction	Automatic			Revolution counter	20		20					
	Niles	1.5	Mahoning River	B. coli absent in 10 cc.; less than 50 bacteria	Yes	4	300 square foot area; mechanical	1 gal. sq. ft. min.	24 hours	Water		Automatic	24 hours	2.5 m.g.		23	0	40-1000	0				
	Port Clinton	0.56	Lake Erie	Normal carbonate alkalinity 3 to 6 p.p.m.	Yes	3	Mechanical	Normal	48-60 hours	Air and water			½-2 hours	2.5 m.g.		10	0	0-600	0				
	Sandusky	4.5	Sandusky Bay	Less than 50 bacteria; no B. coli; turbidity color < 10	Yes	10	Mechanical gravity	125 m.g.a.d.	24 hours	Air and water	Immediately before filters	Automatic	15 hours	15 hours	Revolution counter	4-36	4-10	10-3500	0				
	Steubenville	4.2	Ohio River	No free CO_2; bicarbonate alkalinity 3 to 9 p.p.m.	Sometimes	6	Norwood Engineering Co.	90-121 m.g.a.d.	50 hours	Air and water	Immediately before filters	Automatic	5 hours	12 hours at plant 24 hours down town		0	0	5-300	0				
	Toledo	21.8	Maumee River	3 parts free CO_2 when using alum; 4 parts monocarbonate alkalinity when using Fe and lime	Yes	34	Norwood Engineering Co.	1 m.g.d.	24 hours	Air and water	Filter effluent		3 hours	20 hours	Venturi	10-140	5-45	15-2500	0				
Oregon	Portland	65.0	Bull Run Lake		No											45	13	164					
Pennsylvania	Allentown	12.0	Two springs	No B. coli in 100 cc.	Yes						Clear well	Automatic				Clear		Clear					
	Erie	19.0	Lake Erie	Sterile; no turbidity. Color < 5.	Yes	12	Rapid sand		24 hours	Mechanical washing	Filter effluent	Automatic	3.5 hours	1.5 days	Venturi	0	0	0	0				
	Lancaster	7.23	Conestoga Creek	Less than 50	Yes	15	Maignon design	10 m.g.a.d.	When necessary	Back flush and raking sand	Filter effluent		1 hour	1 day	Venturi	0-30	<5	2-110	0				
	McKeesport	5.0	Youghiogheny and Monongahela	No B. coli in 10 cc.; turbidity 0; hardness < 80	Yes	6	Rapid sand, 1 m. units	113 m.g.a.d.	72 hours	Air and water		Automatic	6-12 hours	24 hours	Venturi	10-35	10	10-9000	0-3				
	Philadelphia	300.0	Delaware and Schuylkill Rivers	Free from B. coli in 1 and 10 cc.	Yes	118	Slow sand	6 m.g.a.d.	77 days	Hand scraping	Filtered water basin				Venturi	Y-0-30 M-0-200	0-70 Trace	0-16,000 50	0				
						189	Rapid sand																
	Reading		Reservoirs and springs			21	Slow sand								Venturi			32.8	0.09				
Rhode Island	Newport	6.5	Impounded surface	Maxima bacteria 10; color 10; alkalinity 6 to 7; turbidity 0	Not very	6	Rapid sand	1½ m.g. per unit	12-24 hours	Air and water	Filter effluent	Automatic	3½ hours		Venturi	36-46	6-10	5-10	0				
	Providence	22.5	Pawtucket river		Yes	10	Slow sand, 1 acre	2-4.5 m.g.a.d.	17 times a year	Hand scraping					Venturi	30-70	17-40	0	0				
South Carolina	Charleston	6.25	Improved reservoir	Color 15; alkalinity 20; hardness 50	No	12	N. Y. C. J.	½ m.g. per unit	24 hours	Water	Filtered water flume		40 hours	8 hours	Type "G" Simplex	48 130	33 18	3	0				
	Columbia	5.5	Congaree River	Count < 25; remove all B. coli type organisms	Yes	6	Mechanical gravity	125 m.g.a.d.	24 hours	Water	Filter effluent		2 hours	16 hours	Pitot tubes			60-1500	0-4				
South Dakota	Huron	0.5	James River	Count 10; no B. coli in 10 cc.		3	Mechanical gravity		24 hours	Air and water	Filter effluent		3 hours	<24 hours				300	1				
Tennessee	Nashville	13.0	Cumberland River	Bacteria < 50; no B. coli	Yes	None					After 3 days sedimentation		3-4 days	3-4 days	Revolution counter			100-3200	7				
Texas	Dallas	7.5			Yes	12	Mechanical	125 m.g.a.d.	24 hours	Air and water	Before filtration		4 days	6 days	Revolution counter		0	5-6500	0				
	Ft. Worth	5.0	Trinity River	U. S. T. D.	Yes	4	Gravity, rapid sand	125 m.g.a.d.	24 hours	Water	After filtration		3 hours	12 hours		10-80	0-10	400 0-5000	0				
Virginia	Lynchburg	6.0	Reservoir on Pedlow River	U. S. T. D.	Yes	None					At reservoir outlet			24 hours		0		0-100					
	Richmond	13.35	James River	Total count 10; no B. coli in 20 cc.; turbidity < 4	Yes	None					Immediately before pumping		12 hours	72 hours	Pitometer	20-50 35	6-20 10	4-500 52	0-7 4				
Washington	Spokane	19.45	Ground																				
Wisconsin	Appleton	4.0	Fox River	97 per cent bacterial reduction; no B. coli in 100 cc.	Yes	4	Mechanical	1 mg.	17-20 hours	Water	After filtration	Automatic	2.5 hours	10 hours	Venturi	50	5	20-1000	0				
	Milwaukee	54.9	Lake Michigan	U. S. T. D.	Yes	None						Automatic			Venturi	0	0	2-30	2-30				
	Superior	2.3	Shallow wells	Less than 0.3 p.p.m. Fe	No	3	Slow sand. 65½ feet x 107½ feet	6.75 m.g.a.d.	Average 16.3 days	Hand scraping			None	None	Venturi	6-48 14	6-42 13						
Canada																							
Alberta	Edmonton	5.25 (Imp.)	Saskatchewan River	As clear and pure as possible	Yes	12	Roberts, gravity	6 m.g.d.		Water	Pump suction		4-5 hours	350,000 gallons. Clear water basin	Venturi		Clear	0-6000	0-50				
British Columbia	New Westminster	9.0	Mountain Lake, glacial		No	None									Venturi	Clear		Clear					
Quebec	Montreal	55.0	St. Lawrence River	Total count < 20	Yes	16	Prefilters, rapid			Prefilters air and water; finals, Blaisdell machine	Main suction well				Venturi	<30	<20	<30	<20				
						16	Slow sand																
	Montreal	30.0	Ottawa and St. Lawrence River	99.9 per cent	Yes	15	Gravity	2 U. S. gal sq. ft. min.	12 hours	Air and water	Filtered water		1 hour	None	Venturi	15-75	3-10	5-100	0-2				
Ontario	Ottawa	24.0	Ottawa River	Coli under 2 per 100 cc.	No						Suction low lift			30 minutes	Venturi	40		6					
Philippine Islands	Manila	17.0	Mariquima River	As much improved as possible	Yes						Intake				Venturi	20-40		0.8					
		2859.4																					

U. S. T. D. = Interstate Carriers Standard of United States Treasury Department.
* = Averages for 1916.
‡ = A particular day's results.

		main pump																												
	Air and water	Effluent from filters	Manual	3 hours	1 hour	Revolution counter	10-30	0-5	100-2000	15-35	Very low	0	44-110	17-85	250-1500	5-40			Always present	97-98 per cent absent	71-568			Rarely	Rarely		2.6-3.3	
							0	0	0.120		0	0			11	6	Agar, 165	Agar 55	1.8 per cent in 1 cc.; 17.2 per cent in 10 cc.	0.2 per cent in 1 cc.; 10.8 per cent in 10 cc.						0.8-1.6	
	Air and water	Effluent from filters		1 hour	4-6 hours	Pitometer	20-250	0-30	25-2000	0	0.39	0	58-340		2230	0-15	Gel. 210	Gel. 77	12 per cent 10 cc. gas			15-850	23-690			1.0		
													230						0.15 per cent cc. confirmed			285	360					
	Water	Effluent from filters		4-6 hours	18 hours	Venturi on L. S.	0-20	0.10	10-285	0			183-274	180-270	52-7300	0-30	Gel. 6-75,000	0-340	Always present	Absent in 10 cc.	227*					4-8		
							12	3.7	139				237	224	1075	7	7203	49										
						Revolution counter	5-60		10-12		0.5-1		300		1-10		Gel. 2-3		Occasionally									
	Air and water	Effluent from filters		2 hours	4 hours	Recording Venturi	0	0	13	0			119	112	40	0.3	241	0.59	1.21	0	85					3		
	Air and water	Effluent from filters		2-3 hours	5 hours	Venturi	20-100	5	0-9000	0	Maximum 2		50-170	20-160	500-200,000	0-500					710-1275	8.3 when algae present		725 for few days			4.5-6.5	
	Air and water	Suction H. S. pump		4.5 hours	None	Venturi on both H. S. and L. S.	25-50	5-10	10-1500	0			82-186	42-154	34-50,500	0-585			22.9 per cubic centimeter	0.081 per cubic centimeter	355-1065						1.7-5.8	
							36.5	5.6	110				134	109	2085	10.9					470							
	Water	Effluent from filters		5.8 hours	1.2 hours	Revolution counter	10-120	0.1-20	10-3000	0			10-290		100-300,000	0-110					0-800			0-800		8-16	1.5-6	
	Air and water	Congulated water	Manual	5 hours	3 hours	Venturi	8-12	5	15-4000	0	Traces		35-115		1250	50	Gel. 5000	45	78.1 per cent of 1/10 cc.	5.8 per cent of 1 cc. 17.3 per cent of 10 cc.		350		170	7			
							Clear		Slight at times				30-35		1-3				None									
	Scrape, washing	Effluent from filters	Manual	48 hours	12 hours	Venturi	10-480	5-35	3-338	0-3	0.9-3	0.1-0.7	188-259	81-258	235-3500	0-20	180-15,000	0-150	1173 per 100 cc.	0.64 per 100 cc.	Variable				50-750		1-2.5	
	Water			4 hours	None	Tachometer	53	12	39	0	1.9	0.26	237	238	1722	5	9											
	Air and water	Clear well		2½-3 hours	½-1 hour	Revolution counter	34	14	138	0	Small		195	185			Gel. 3200	38			280					8.5		
							36-58	20-45			No	Trace	260-580	140-460	50-640	0-58	Gel. 80-1800	0-140	Present in summer	5 per cent of 1 cc. 20 per cent of 10 cc.	185					2.73		
	Air and water	Effluent from filters		½-1 hour	3 hours (maximum)	Revolution counter	0-100	0-10	0-3000	0	0.3	0.3	300	220	230	18	360	39	1-1000 per cubic centimeter	Less than one	21-285	8.3				10-15	2.1-4.3	
									90				50-250	20-240	100-50,000	0-100	Gel. 1000-1,000,000	0-1000								
		After sedimentation		5-6 days	None	Pitometer	0-80	0-60	50-12000	0-50	0.2-0.5		200	190			5000-150,000	5-200			140-425	8.3			71-210		1.7-2.5	
							15	10	2500	4				100-250			24,000	48			210	In summer			125		2-1	
	Air and water	After coagulation		24 hours		Revolution counter	30-80	3-30	3-3000	0-15			71-174	32-165			Gel. 5890	18			521						4.5	
		Effluent gallery	Automatic			Venturi	Trace	None	15	3	0.6	0.6	243	243	80	7	535	43	44.5 per cent of 5 cc.	3 per cent of 1 cc. 7.4 per cent of 5 cc. 7.4 per cent of 10 cc.						3.5		
			Automatic	1 week	1 week	Revolution counter			400+	5-15											152				142	10-12		
	Water	After coagulation	Manual	4-8 or 12 hours	24 hours	Revolution counter	0	0	Maximum 600 Average 400	0	2-20 7	0.1-2.0 1	20-80 55	15-70 45	L. L. A. 2000	5	Gel. 25,000	50	100 per cubic centimeter	1 per 300 cc.	142					7.5	1.8	
	Air and water			6 hours	6 hours	Revolution counter	10-100	5-50	70-800	0			70-130	60-120	2000-70,000	0-400			Variable		11-570							
106	Water	Effluent from filters	Automatic	12 hours	None	Venturi	8-20	3-6	60-2400	0-3	0.3	Trace	53-175	25-75	400-9500	1-120	Gel. 500-7500	2-650	35 per cent 1 cc.	5 per cent of 10 cc.		0-170	440-1150		1.76-7.92	0.83-1.3		
							10	5	600	0			94	37	200	14	2900	38				62.5	770		4.39	1.19		
											0.05				L. L. A. 2				None									
	Water Scraping	None used		2 hours	4 hours	Venturi	38	0	25	0	2.25 Minimum 1.9	0.2 0.00	23															
	Air and water	Filter surface		2½-24 hours	2½-24 hours	Venturi	41	9	63	0			212	204	357	2	1220	5	318 days in 1 cc.	1 day in 1 cc.	253.2					2.9		
	High velocity water	Before filters	Automatic	2-4 hours	6-8 hours	Venturi	16-68	3-23	3-126	0	Trace		103-251	32-123	80	3	1340	4	5.700 in 1 cc.	0.00672 in 1 cc.	132			1290		6		
							33	7	13				300	53														
	Water	After filtration	Automatic	3-6 hours	36 hours	Venturi	21-84	9-27	1-150	0	0.11-0.66	0.03-.07	77-202	52-190	775	7	2250	24	15 per cubic centimeter	0.2 per 100 cc.	346					2.5		
							41	12	18		0.33	0.05	153	134														
	Water	After filtration	For alum	30-40 hours	1 day	Venturi	12-80	9-18	25-4800	0		0.005	74-258	26-111	300-79,000	2-125	11,000-500,000	26-1070	0-265	0.0024-0.0425	0-234		0-355	430-862			0-4	
			Nor for iron and lime	5-6 hours			35	11	1500	0			142	52	12,000	16	81,000	170	21	0.0166	85		94	743			1.45	
	Air and water	Part in raw; part in filtered	Automatic	3 hours	2 hours	Venturi	3-6	0	0-315	0			134-197				Gel. 1436	6	36.42 per cent of 1 cc.	0	61				6.4			
		Suction well	Manual	48-72 hours	48 hours	Venturi	3.5 6-10	0-10	10.8 50-1200	0-5			165 96-260	80-260		30	Gel. 20,000	60	98 per cent of 1 cc.	0	177			142		2.5		
																	Agar, 12,000	50										
	Air and water	Effluent from filters		4.14 hours	10 days	Venturi	32	9	7	0	0.1	0	18-32	20					65 per cent positive		155				14.5	1.7	8.3	
	Air and water	Effluent		2½-5 hours	1 week	Pitometer	10-80	3-15	2-2000	0-3			26 5-40	5-30			10,000	6	98 per cent of 1 cc.	5 per cent of 10 cc.	81-109					1.7		
	Water, scraping	Effluent		12-14 hours	1 hour	Venturi	41	23	2.3	0	0.2	0.2	68	66	Neutral bile agar, 135 Agar, 975 5-50	9 3	Gel. 51,525	22	45	0	308					4.0		
		Suction well	Automatic														Gel. 10-80		11.3 per cent of 10 cc.									
	Water	Effluent of filters	Automatic	None	None	Venturi	5-65	0-10	1-50	0			8-19	7.5-19	850	0-50	Gel. 17,500	0-40	0/5-5/5, Av. 2/5	0/5	35-71	2-3				4.7		
							20	4	20				12	11		8		10										
	Water	Intake	Automatic	5 hours	None	Simplex			10-200			0.2	15-80	15-60			1000	20	Present	Rarely in 10 cc.; never in 1 cc.	50-100						2.5-3.5	
							20	20	0	0	0.05	0.05	32	33	480	38			Present in 1 cc.	Absent in 10 cc.		2.5				1.5-3.75		
					Varies	Venturi	13-27	5-23	1-5	1-6	0-0.5	0.1-0.2	19-36	28-32	3-500	2-480			3 per cent of 1/10 cc.; 11 per cent of 1 cc.; 40 per cent of 10 cc.	2 per cent of 1 cc.; 19 per cent of 10 cc.								
							18	14	2	2	0.2	0.16	28	31	62	18												
	Air and water	Effluent from filters		4 hours	2 hours		Trace	Trace	10-2000				101	90			600-50,000	0-50	75 per cent of 1/10 cc. +	15 per cent 10 cc.	85				4.75			
	Ejector system	Raw and filtered		20 hours	3-5 days	Venturi	25-70	0-35	12-600	0			30-57	24-56	1,001	0-10	Gel. 5509	0-14		0.24 per cent 1 cc.; 1.44 per cent 10 cc.								
							40.6	9.2	52.5				44.3	37.7		3		4		Absent								
																	Gel. 3			Absent								
		At Venturi from reservoir	Automatic										14.1		110	12			11.5 per cent	1.5 per cent								
	Water	Effluent from reservoir		3 hours	1 day	Venturi	40-140	0-50	2-10	0.6	0.2-0.4	0-0.2	10-35	4.20			Gel. 200-50,000	0-1500 20			200-450						1.7-8.3	
	Scraping	Effluent from reservoir			1 hour or less	Venturi	22	13	5.2	0			8	8.7			Gel. 300-31,000	21	91.8 per cent of 1 cc.							12-20	2-3	
	Air and water	Clear well		6 hours			60-300	0-30	10-1000	0-30	Trace		5-9	10	400	8	1476	19	7 per cubic centimeter	4 per 1000 cc.	327				140		3.3	
	Water, 21 inch rise	Suction well		24 hours	30 m.g. basin	Venturi	33	12	11	0	0.43	0.05	70	58	246	11	1827	34	Index 1.295	0.009	214						1.80	
	Water, 24 inch rise	Effluent from filters		3 hours	20 minutes	Revolution counter	20-40	3-20	5-1400	0	0.5-3.5	0-0.1	12-210	5-205	1500 (acid formers	40 Acid	5000	80	Always in 1 cc.	33 per cent of 10 cc.	17-640					2.5-4.1		
							25	12	35		1.0	0.02	130	120	520)	formers rare				Rarely in 1 cc.	157					3.7		
	Air and water	Before filtration		6 hours	4 hours		Yellow	Clear blue	90	10			50-80	20-40							200-800					16		
	High velocity washing	Effluent from filters		6-12 hours	6-12 hours		5-25	3-12	3-4000	0-tr.	0.01-0.05	0.01-.10	22-62	33-60			100-310,000	2-480	0.1-1000	0-1		106-355	64-142			0.3-1.8		
							10	7	185		0.03	0.05	35	41			13,900	48	21.56 per cubic centimeter	0.07198 per cubic centimeter		187	106			1.1		
		Pump suction	Automatic	3 hours	<4 hours	Venturi (raw)	<10		15		Very low		90		106	19									5-12			
	Water	As applied to filters	Automatic	18 hours	12 hours	Venturi	29	4	58	0			170	51			8027*	24*	44 per cubic centimeter*	0.084 per cubic centimeter	284		1206		5		732	
						Venturi and pitometer			0		0.15		282		0-9		3-7		1/13 in 10 cc									
ded	Water	Clear well		4 hours	None	Venturi	"Mud"	Clearer	50-1900	20-100			90±	80±	9000	6000	40,000	27,000			0-or 71-284		142-568	25		8		
		Pump suction	Automatic			Revolution counter	20		20		0.1-1.0		100-200				720	60	Present	Absent						8	1.8	
	Water		Automatic	24 hours	2.5 m.g.		23	0	40-1000	0	0-8	0	20-150		200-210,000	0-180	2000-100,000	0-500	Up to 400 per cubic centimeter	0 in 10 cc.			Min. 213				4.1-6.2	
	Air and water			1-2 hours	2.5 m.g.		10	0	0-600	0	16.4	0.4	82-124	50-90	1050‡	0‡	1540‡	0‡	Present	Absent			300		370			
	Air and water	Immediately before filters	Automatic	15 hours	15 hours	Revolution counter	4-36	4-10	10-3500	0	2.0	0.5-1.0	85-120	70-105			500-350,000	0-120	95 per cent of 1 cc.	1/10 per cent of 1 cc.					7.5			
	Air and water	Immediately before filters	Automatic	5 hours	12 hours at plant 24 hours down town		0	0	5-300	0		<0.2		20-30	10-70,000	2	100-500,000	4	20	0		0-295		85-355	3-6.2			
	Air and water	Filter effluent		3 hours	20 hours	Venturi	10-140	5-45	15-2500	0	0.1-3.5	Tr.-0.15	66-241	27-156			200-318,500	1-260	Index 23.42	Index 0.011	152		238		667	6.2		
							45	13	164		1.5	0.1	156	63			22,002	34										
		Clear well	Automatic				Clear		Clear		0.8				4			0								0.8		
	Mechanical washing	Filter effluent	Automatic	3.5 hours	1.5 days	Venturi	0-30	<5	2-110	0			100	98-99	40-200	0-4	200-6000	5-40	30 per cent of samples	0	28					3.5		
essary	Back flush and raking sand	Filter effluent		1 hour	1 day	Venturi	10-35	10	10-9000	0-3	1		80-140				Gel. 7000	38	Present in 1 cc.		383					1.5		
	Air and water		Automatic	6-12 hours	24 hours	Venturi	Y-0-30 M-0-200	0-70 Trace	0-16,000 50	0	0.5-9.0 1.2	0-6 0.3	Acid 40-90 60	15-50 30	1400	7	3000	40	Y-35 per cent of 1 cc. M-70 per cent of 1 cc.	19 times in 10 cc. in 16 years			100-3800 868				0-1450 700	
	Hand scraping	Filtered water basin																								1.2		
				3½ hours		Venturi			32.8	0.09							Gel. 2167	48										
n	Air and water	Filter effluent	Automatic			Venturi	36-46	6-10	5-10	0			10-25	6-20	200-1500	0-10	200-5000	0-10	0.0-0.5 per cubic centimeter	0	71-213	1-10 when used				2.5-5.0		14-35
year	Hand scraping					Venturi	30-70	17-40	0	0			6-16	6-15	100-25,000	1-150			Present in 1/100 cc.	Frequent in 10 cc.; seldom 1 cc.								
							48	33					10.6	10	1300	10												
	Water	Filtered water flume		40 hours	8 hours	Type "G" Simplex	130	18	3	0	1.0	0.05	12	20	650	80			0	0	284				94	16		
	Water	Filter effluent		2 hours	16 hours	Pitot tubes			60-1500	0-4			6-22		300-2000	15					220							
									300	1			12															
	Air and water	Filter effluent		3 hours	<24 hours										500	5-10			Present in 5 cc. in winter	0 in 10 cc.	635					5.0		
																			Present in 1/10 cc. in summer									
		After 3 days sedimentation		3-4 days	3-4 days	Revolution counter			100-3200	7					2500-3500	24-70			Practically always		142-426					7.1		
	Air and water	Before filtration		4 days	6 days	Revolution counter		0	5-6500 400	0			100-340 192	20-180 96			Gel. 70-148,000 6951	0-430 39					210	450			3.0	
	Water	After filtration		3 hours	12 hours		10-80	0-10	0-5000	0	0.3	0-0.1	200	60	300	4-5			100 per cent of 1 cc.	<5 per cent of 10 cc.			284		852		1.7	
		At reservoir outlet			24 hours		0		0-100		0.1		10-22		50-300				0-1 in 10 cc.	0		2.8						
		Immediately before pumping		12 hours	72 hours	Pitometer	20-50	6-20	4-500	0-7	Trace	Trace	8-70	8-45	250	12					100-560						1.66-4.92	
							35	10	52	4			37	26							245						3.05	
s	Water	After filtration	Automatic	2.5 hours	10 hours	Venturi	50	5	20-1000	0			160	152	100	3	2000	18	85 per cent of 1 cc.	4 per cent of 1 cc.	142						2.1	
			Automatic			Venturi	0	0	2-30	2-30	0.24	0.24	124	124	22-2800	1-85	1060-19,660	0-1440	98.2 per cent of 10 cc.	21.9 per cent of 1 cc.							2.0-3.1	
3 days	Hand scraping			None	None	Venturi	6-48	6-42			0.2-0.5	0.1-0.15	44				Gel. 0-220	0-30	Rare in 5 cc.	0								
							14	13			0.3	0.1					25.2	4.6										
	Water	Pump suction		4-5 hours	350,000 gallons. Clear water basin	Venturi		Clear	0-6000	0-50	0	0	143-240		30-2000	0-40	Gel. 68-3200	0-1200	0	0						8-14		
						Venturi	Clear		Clear		0				500-10,000				0									
	Prefilters air and water; finals. Blaisdell machine	Main suction well				Venturi	<20	<20	<20	<20			40-100				1700	17±	24 per 10 cc.							5-20		
	Air and water	Filtered water		1 hour	None	Venturi	15-75	3-10	5-100	0-2	0.3	0.2	18-95	6-90	6-5000		100-500,000		50 per cubic centimeter		120					2.9		
		Suction low lift			30 minutes	Venturi	40		6		0.55		24		250	6	1049	12	66.8 per 100 cc.	0.26 per 100 cc.						23		
		Intake				Venturi	20-40		0.8		0.2		100±		760	336			0.15 per cubic centimeter	0.06 per cubic centimeter						8.3		



and bacteriological work must be entered into. If the laboratory man is also an engineer, so much the better.

The author was surprised on first preparing his record to see how recently the laboratories listed had been installed. Beginning with the one maintained by the city of New York since 1897 and that of Utica, N. Y., established in the same year, a rapidly increasing number of laboratories was established during the succeeding 19 years. Six plants with a combined averge pumpage of 32.5 million gallons per day are now installing laboratories.

TABLE 3

Increase in laboratory control of water purification plants by plant or department laboratories

YEAR	AVERAGE DAILY PUMPAGE, HUNDRED MILLION GALLONS	POPULATION, 1910, MILLIONS	NUMBER OF PLANTS
1897	5.6	5.8	2
1898	5.6	5.8	2
1899	5.8	5.9	3
1900	5.8	5.9	3
1901	5.8	5.9	3
1902	6.2	6.05	.5
1903	6.3	6.1	6
1904	6.6	6.4	8
1905	6.9	6.65	10
1906	.0	7.5	15
1907	8.6	7.9	17
1908	8.8	8.15	19
1909	9.5	8.85	26
1910	10.9	9.75	34
1911	11.4	10.1	41
1912	12.0	10.6	50
1913	13.1	11.5	57
1914	13.7	11.75	61
1915	14.7	12.50	74
1916	14.8	12.65	77
1917	15.5	12.75	83

Twelve plants with a combined pumpage of 45,000,000 gallons per day have daily examinations made at outside laboratories. The Metropolitan Water District which supplies Boston and some neighboring communities is under a state commission. It maintains its own laboratory and supplies a little more than 100,000,000 of gallons of water daily.

Of the plants reporting, 23 are owned privately, 72 municipally and one by the United States government. The employees of 29 of

the municipally owned plants and those of the government plant are selected by civil service methods.

Rivers and streams form the direct source of 68 plants out of the 96 that have their own laboratories, the remaining sources are lakes, impounded waters from more or less satisfactorily protected watersheds and, in a few instances, wells and infiltration galleries. Those plants which do not maintain laboratories are nearly all using the water of wells or impounding reservoirs. None of them supplies more than an average pumpage of 16,000,000 gallons per day. One or two pump directly from streams without treatment.

The quantity of the laboratory work done as well as the particular determinations made are dependent upon local conditions. For instance, there is very little use in determining iron every day unless the raw water contains that metal in sufficient quantities to precipitate or aid the growth of iron-secreting organisms.

Color and turbidity are usually determined on the raw and treated supplies if the water is coagulated and filtered. These factors give a somewhat rough indication of the efficiency of the treatment. Alkalinity is another common determination, since it limits the amount of coagulant which may be put into a water without the addition of alkaline substances such as lime, soda ash or bicarbonate of soda. Free carbon dioxide is carefully watched in some plants, particularly those that soften the water, remove iron, or use the iron and lime process. Incrustants and other matters are determined where the conditions justify.

Occasional complete sanitary chemical examinations are usually considered sufficient, since chemical standards based upon the ordinary factors of a sanitary analysis often mean very little when applied to the routine examination of a treated water. As a matter of fact the oxidation of nitrogen in one of our rapid sand filters is almost negligible and any evidences of pollution which appear in the raw water will be but slightly modified. This state of affairs has led to error on the part of individuals who have attempted to judge a treated water upon the basis of the commonly stated chemical standards. In the case of stored or impounded waters considerable oxidation may take place and the determination of the nitrogen factors may become of greater importance.

Mineral analyses are valuable to users of water for steam-making, but those individual firms which enter seriously into the problem of softening a supply usually make their own determinations of a few

important factors. There are quite a few boiler plants in most communities which use proprietary boiler compounds, prepared upon the basis of special analyses by the manufacturers of the compounds or upon the examinations of the laboratory of the water plant. Of course, an analysis of the city water showing its excellence for all industrial purposes is a good advertisement.

In general, however, it may be said that a quarterly mineral analysis, a weekly or monthly sanitary chemical analysis and routine determinations of color, turbidity, temperature, alkalinity, free carbon dioxide, free chlorine and the like, ought to meet all demands for chemical examinations. In discussing chemical determinations, very little reference to the procedures is necessary since the procedures laid down in the Standard Methods of Water Analysis of the American Public Health Association are so universally followed.

Plankton examinations are made by but 32 of the plants listed. In many cases they are not necessary. Where water is impounded or stored in open reservoirs, routine plankton examinations are useful in indicating the proper time for copper treatment before odors and tastes due to algae growths have become objectionable.

When working with a treated water, the bacteriological determinations are of the highest importance. In most instances they determine the efficiency and adequacy of the treatment given. The arbitrary standards of efficiency applied to water treatment are rapidly becoming more and more rigid. The original filters which the New Chelsea Water Company of London installed about 1829 were considered efficient if they merely removed the turbidity of the Thames water. Then a good many years later came Koch's standard of a maximum of 100 bacteria per cubic centimeter. This standard was applied to water of all kinds. Later a standard based upon a percentage removal of bacteria came into vogue. The percentage standard of plant efficiency is not satisfactory, because when one is treating a good raw water the product may show a low percentage efficiency and yet actually be of the best quality. On the other hand when the raw water is high in bacteria the effluent may be high also and still be within the limit set up. For example, 99 per cent efficiency in the operation of the Iowa City plant at one time last winter would have allowed a bacterial count of 8,800 because the raw water had a bacterial count of 880,000.

Within the past year or so, Wolman of the Maryland State Board

of Health has proposed a logarithmic ratio standard which has some advantages. It requires that the ratio of the logarithm of the number of bacteria in the raw water to the logarithm of the number of bacteria in the treated water shall not be less than 2.5 to 1. In effect it requires that as the contamination of the raw water increases, the efficiency of operation must increase at a more rapid rate. This standard undoubtedly has its limitations but it is a convenient device for supervision of operation of a number of plants.

At the same time that the strictly numerical bacterial standards of operation have been evolving, other standards based upon the freedom of the water from certain kinds of bacteria, such as the colon bacillus and the sewage streptococci, have been developing also. In this country the sewage streptococci have been worked with but little, while in Europe, particularly in Germany, the validity of American conclusions based upon work on the B. coli has been questioned. The author believes, however, that the present European tendency is to place more faith in the B. coli determinations than in the past.

There exists considerable difference of opinion as to the maximum number of bacteria of the colon type which may be allowed in safe water. The presence of B. coli in 1 cc. quantities of the water, except occasionally found organisms, is generally recognized as sufficient to condemn a supply. In addition it has been said that it should be absent from the majority of 10 cc. samples of the treated water. Constant absence in 5, 10, 50 and even 100 cc. has been recommended. A few years ago the United States Treasury Department standard for water supplied to trains carrying passengers in interstate traffic was promulgated. Briefly this standard required that a water should not contain more than 100 bacteria at 37°C. and that not more than one out of five 10-cc. plantings of the water into lactose broth should show the colon bacillus. This was practically equivalent to setting a limit for colon at one in 50 cc. This standard was adopted as the majority report of the committee appointed. It aroused considerable opposition from the water men when first adopted, but the government officials explained that it was not intended for city supplies, but for the small amount of water supplied to passengers. Since then it has been required that bottled spring waters and mineral waters should pass this Treasury Department test.

In the last column of table 1, under the head "Working Standard,"

are given the standards which the officials of the different plants have set up for their use. Many of these are working to the Treasury Department standard, a few are working to even higher standards, while some mention only a removal of turbidity and color. The author is inclined to believe, however, in these latter cases that some standard of bacterial purity was intended to be understood.

Some of the standards listed are very high and with some waters would be practically impossible to achieve except at a very high cost. This points to the fact that arbitrary standards are apt to be unjust in that they require all waters to reach a certain degree of purity which may not be essential to the safety of the supply.

The practical uniformity of procedure which can be noticed in the chemical determinations of a water analysis has not existed in the bacteriological procedures, due in part to the changes and ambiguity which were introduced by the committee into the second edition of the *Standard Methods of Water Analysis*. The third edition, which was published in 1917, is furnished with a much clearer statement of bacterial methods and no doubt will aid materially to clear away the confusion which exists.

In considering the methods used, the least variation will be found in the plating, because the possibilities for variation are not so great. In the body temperature determinations some workers use litmus lactose agar, which gives the opportunity of recognizing acid-forming bacteria in addition to the count, and others use the plain nutrient agar. At 20°C., many of the older laboratories use gelatine while others employ agar on account of its lack of trouble with liquefiers and its general convenience. In some laboratories the 37°C. or body count is omitted, while in more laboratories the 20°C. count is omitted on account of the recommendation of the committee in the second edition of *Standard Methods*. Fortunately the third edition has restored the 20°C. count.

In regard to the colon bacillus, there is the greatest diversity of method. Some are satisfied with gas formation in dextrose or lactose broth at the risk of calling a considerable number of tests positive when the gas formation is due to other organisms than the colon bacillus. Some prefer lactose bile. Others make confirmatory tests on all gas-bearing tubes. These confirmatory tests vary widely. They may consist in making simple streaks on litmus lactose agar or on Endo's fuchsine-sulphate medium, or they may extend to cultures in a series of sugar media, motility, Gram's stain and so on.

The new *Standard Methods* have prescribed a method using litmus lactose agar and lactose agar which will undoubtedly come rapidly into use and enable one to know on reading a report whether either of the two discriminating methods of identifying the colon bacillus have been adopted.

The chief business of most of the laboratories listed in the tables is the control of the water supply, but many of them further justify their existence by making examinations of other substances. Where time permits or sufficient assistance is provided, the chemicals used in the water purification may be made, as well as the coal, oils and so on. Purchases of these substances under the usual guarantees may be enforced, often at a considerable saving.

In city work, food and drug inspection, the milk supply and its inspection, the examination of cement, paving materials, and all city supplies may be put under the control of the laboratory chief.

Where the laboratory men are trained in that line of work, the city laboratory may make the examinations of the board of health's routine. These include specimens of blood for diagnosis of typhoid, sputum for tuberculosis, throat cultures for diphtheria and so on. Some of the last may be reported from ten to twenty-four hours sooner than the state laboratory could report, and a difference of this much time sometimes means saving a life.

The author has merely mentioned these possibilities of the extension of the scope of the laboratory to show how it can be made to serve the community in other fields. We, of course, should maintain that the first duty of the water laboratory is to maintain an economical treatment of the water supply which will insure a safe water at all times.

In the consideration of table 2 it is hard to draw general conclusions other than that most of the plants are operating efficiently. All do not treat the same sort of water by any means. The variation in turbidity, color, alkalinity and bacterial content of the raw water is very great. The turbidities range up to 12,000, the color to 480 and the alkalinity from -90 to $+580$. The maximum body temperature count of bacteria on the raw water is 210,000; the maximum of the 20° count is 1,000,000 organisms per cubic centimeter.

In going over the tables of chemicals used, the variation in the necessary doses is clear. The short summary of the figures on the next page is self-explanatory.

TABLE 4

	MAXIMUM IN POUNDS PER MILLION GALLONS	AVERAGE OF MAXIMUM FIGURES, POUNDS PER MILLION GALLONS
Aluminum sulphate	1275.0	334.5
Iron sulphate	850.0	349.0
Lime	3800.0	915.0
Hydrated lime	852.0	316.0
Calcium hypochlorite	20.0	9.5
Chlorine	6.5	3.2

Other factors of special interest are the sedimentation period and the storage period of the treated waters. For most of the rapid sand plants the coagulation period is less than six hours. About one-fourth of these plants have a storage of treated water of less than one hour—a condition which may often lead to difficulties in case of fire. The maximum storage of filtered water reported is as great as ten days, but the average is about six hours. The generally adopted rate of operation is 125,000,000 gallons per acre per day.

In conclusion, it should be remarked that the practice in the plants which are listed, is changing from day to day. In the time that the author has been collecting and tabulating these data, it is inevitable that some alterations have been made. The author has endeavored to make the tabulations as accurate as possible and he believes that they actually represent conditions in the water works industry up to the middle of 1917.

RECOVERING A PUMP LOST IN A DEEP WELL[1]

By W. A. Judd

Well no. 9 at Mason City starts with a 19-inch hole which continues for 225 feet. At that point the diameter is reduced to 16 inches and at 540 feet it is again reduced to 12 inches. The well is 1200 feet deep. In this well is installed a five-stage 17-inch American deep-well motor-driven turbine. The turbine proper is about 90 feet below the well curb and below the turbine are two lengths of 9-inch suction pipe. Water normally stands in the well about 85 feet below the curb and pumps down about 7 feet when yielding 1200 gallons per minute.

The construction of this type of pump and its connections are well known. The weight of the pump is carried by the 10-inch flanged discharge pipe in 8-foot lengths. Inside this discharge pipe is another pipe, 4 inches in outside diameter, held in position by spiders inserted in the flanges of the discharge pipe. This pipe is connected together by screw couplings which also serve to hold the shaft bearings. Inside this pipe is the shaft.

The pump is overhauled each year. On New Year's day, 1917, the pump had been lowered together with four lengths of discharge pipe, shaft casing and shafting. The fifth length of shafting had been screwed up tight and the fifth shaft casing was being set up solid when, without any warning, casing and shaft disappeared through the discharge pipe and with the pump and two lengths of discharge pipe went bubbling down to find a resting place on the ledge 225 feet below the surface. The two remaining lengths of discharge pipe were pulled out and it was found that in making up the shaft casing joint, the discharge pipe had worked loose from the flange.

A well driller's advice was immediately sought, and he recommended trying to couple on to the shafting, which projects about a foot above the bearings. One of the shaft couplings was taken to a machine shop and the threads recut to make a loose fit. One end was tapered out on the inside and the other end was cut down to

[1] Read before the Iowa Section, October 10, 1917.

take a 2-inch pipe coupling. On the bottom was soldered a heavy funnel to center the coupling over the shaft. Two-inch pipe was then cut into about 10-feet lengths for ease in handling and threaded. Because the shafting has a left-hand thread, it was necessary to drill each pipe coupling after the joint was made up and pin the pipe and coupling together. This was a tedious process, but finally the funnel was heard to strike the shaft. It was then raised and lowered a few times to be sure of centering and the men began to twist the pipe to the left. After several attempts, it seemed to take hold and hoisting was attempted with an 8-ton chain hoist which hangs from a trolley running on a 15-inch I-beam near the roof of the pump house. From the hard pull, it was known that the coupling caught hold of the shaft, but at about the third pull on the chain, the coupling became loose and for a day the men fished continuously without getting another nibble. The string of pipe was then pulled out and it was found that the funnel had bent over, allowing the shaft to center in the funnel to one side of the coupling. A heavier funnel was built, reinforced with steel ribs and bands, but even with this there was no luck, the shaft turning every time the threads engaged.

During this time one of the men had been telling of a fishing tool he had heard of, consisting of two rings. Just how the rings were operated no one knew until the blacksmith started to make such a tool. The small end of the funnel was cut off so the hole through it was about 5 inches in diameter. A fork was made to which the funnel was riveted. Above the fork was welded a piece of 2-inch shafting 3 feet long in such a way that when the shaft and funnel were vertical, the face of the steel was about $2\frac{1}{2}$ inches from a vertical line drawn through the center of the funnel. On the back of this bar, two ears were welded and punched for a 1-inch bolt. Two open rings were made, 5 inches in diameter, of $\frac{3}{4}$ inch square steel with the ends bent back, flattened out and punched for a 1-inch bolt. The top of the bar had a piece of 2-inch pipe welded to it, the rings were bolted to their places and wired together so they would move together on the bolts and a light wire was fastened to the top ring to hold them in a horizontal position.

The whole apparatus was then lowered into the well with the same 2-inch pipe, the wire being paid out as the tool descended. The funnel centered the tool over the shaft casing all right, but when the rings were dropped by slacking on the wire, they did not bite into the casing enough to stand a pull so the tool was again pulled out,

a tool-steel face put on the rings, and then notched. A piece of flat tool steel was welded to the face of the vertical bar, and in it were cut some teeth, making it look like a wood rasp. The tool was again lowered and caught hold of the shaft casing with a grip that scarcely anything could disengage. At the first pull it was evident that the pump was wedged tightly into the well, for instead of the pump rising, the I-beam above was bending. Men were sent for props to put under the beam, but while they were gone, the tension on the hoist suddenly slackened, showing that the pump was loose in the well and pulling was started. After pulling continuously for several hours the pump was landed on blocking on the well curb and those who had been fairly on needles for a week went home and to sleep undisturbed by dreams of a big fire and no water.

PRICES AND DEPRECIATION OF CAST IRON PIPE[1]

By Burt B. Hodgman

The history of the prices of cast iron pipe, showing the changes in price during the past fifty years or more, is particularly interesting at this time. Some of the data presented are confusing in one respect, because it is not known whether the prices paid were for pipe by the ton of 2240 or 2000 pounds.

The author has compiled table 1 showing the prices paid for cast iron pipe by the city of Boston, Mass., from 1868 to 1917. This is based on the cost of 6-inch pipe during that entire period and it is interesting to note that the present prices are not as high as the maximum prices paid during the period covered. The prices are based on the long ton from 1868 to 1896 and on the short ton from 1896 to 1917 inclusive. In 1868 Boston paid $78 per ton for 6-inch pipe. In 1873 they paid $67, while in 1897 it was purchased for $16.20 per ton, and this year the price is again up to $45 per ton.

In 1832, 10-inch pipe was purchased by the City of Richmond, Va., from Samuel and Thos. S. Richards of Philadelphia for $1.38 per foot, the pipe being in 9-foot lengths and $\frac{9}{16}$ in thickness. This amounts to about $54 per ton of 2000 pounds; the price was for pipe delivered at Richmond. The prices paid per foot were: 3-inch, $0.37; 4-inch, $0.45; 6-inch, $0.70; 8-inch, $1.25. In 1844, 3-inch pipe was bought for $0.30 per foot and in 1854 16- and 8-inch pipe was purchased from R. and S. H. Jones at $52.50 per long ton. The pipe was cast at Florence, N. J. In 1832, 10-inch valves were purchased in Richmond at $70, 8-inch valves at $56, 6-inch valves at $44.50, 4-inch valves at $30, and 3-inch valves at $28.

It is the belief of the author, after considerable experience in examining cast iron water mains that have been in service all the way up to one hundred years and under almost every condition known in the United States, that the leading cause of depreciation is the corrosion, sedimentation or incrustation which occurs on the interior of water mains.

[1] Read before the Richmond Convention, May 9, 1917.

TABLE 1

*Cost of 6-inch cast iron pipe at Boston, Mass.**

YEAR	PRICE PAID	FROM WHOM PURCHASED
1868	$78.40	R. D. Wood & Company
1870	52.00	S. Fulton & Company
1871	57.50	J. W. Starr
1873	67.20	Gloucester Iron Works
1874	51.00	R. D. Wood & Company
1875	42.00	J. W. Starr
1876	35.00	J. W. Starr
1877	30.00	J. W. Starr
1878	26.47	Warren Foundry & Machine Works
1879	25.20	McNeal Pipe & Foundry Company
1880	42.00	J. W. Starr
1881	31.90	McNeal Pipe & Foundry Company
1882	39.00	Camden Iron Works
1883	36.80	R. D. Wood & Company
1884	34.75	Donaldson & Thomas
1885	29.19	McNeal Pipe & Foundry Company
1886	29.40	R. D. Wood & Company
1887	33.09	Gloucester Iron Works
1888	28.45	McNeal Pipe & Foundry Company
1889	28.31	Gloucester Iron Works
1890	30.34	R. D. Wood & Company
1891	27.95	R. D. Wood & Company
1892	25.40	Radford Pipe & Iron Co.
1893	25.94	R. D. Wood & Company
1894	22.45	McNeal Pipe & Foundry Company
1895	21.60	R. D. Wood & Company
1896	20.25	R. D. Wood & Company
1897	17.17	McNeal Pipe & Foundry Company
1898	16.75	Warren Foundry & Machine Company
1899	16.70	Warran Foundry & Machine Company
1900	26.00	Warren Foundry & Machine Company
1901	20.40	U. S. Cast Iron Pipe & Foundry Company
1902	26.45	U. S. Cast Iron Pipe & Foundry Company
1903	29.70	U. S. Cast Iron Pipe & Foundry Company
1904	22.30	U. S. Cast Iron Pipe & Foundry Company
1905	26.20	U. S. Cast Iron Pipe & Foundry Company
1906	30.70	U. S. Cast Iron Pipe & Foundry Company
1907	35.00	U. S. Cast Iron Pipe & Foundry Company
1908	24.50	Warren Foundry & Machine Company

* The long ton was used until the 1895 contract with the McNeal Pipe & Foundry Company, when the short ton came into use. Prices furnished by C. J. Carven, Engineer of Water and Sewer Division, Department of Public Works, Boston.

TABLE 1—*Continued*

YEAR	PRICE PAID	FROM WHOM PURCHASED
1909	23.30	Florence Iron Works
1910	24.60	Florence Iron Works
1911	20.70	U. S. Cast Iron Pipe & Foundry Company
1912	20.95	U. S. Cast Iron Pipe & Foundry Company
1913	23.60	U. S. Cast Iron Pipe & Foundry Company
1913	20.85	U. S. Cast Iron Pipe & Foundry Company
1914	21.10	Florence Iron Works
1915	20.95	Standard Cast Iron Pipe & Foundry Company
1916	29.24	R. D. Wood & Company
1917	45.50	R. D. Wood & Company

About two years ago questions were sent to water works superintendents and engineers all over the United States, asking for their experience with various kinds of water mains. Answers were received covering users of more than 15,000 miles of cast iron pipe and are summarized in Table 2. These answers came from nearly every State in the Union and almost without exception the answers stated that the outside surface of the iron was in excellent condition. There were some exceptions, but where those exceptions occurred there was some special condition covering them. This of course does not cover the subject of electrolysis, but that should be considered a special condition, the same as the pitting on the outside which occurs in cast iron mains laid in peat bogs or in cinders.

Incrustation or scale results from several different causes. Probably the principal is iron corrosion due to soft waters which are likely to contain free carbonic acid, crenothrix, or some kindred source of trouble, such as manganese, sulphur, organic or mineral acids, all of which will greatly accelerate the incrustation of these mains. Also it should be noted that greater corrosion takes place in pipes which have free iron exposed, as is the case where the line is frequently tapped. This may be due to galvanic action. It is, nevertheless, a fact that the same water passing through a tar-coated line which has not been tapped will affect that pipe less rapidly than where corporation cocks have been placed at frequent intervals.

There are other incrustants, such as pipe, sponge, pipe moss, etc., but it is not the author's object to discuss them from a chemist's standpoint, as this was very thoroughly covered by N. S. Hill, Jr., in a paper read before this Association in 1907.

TABLE 2

Summary of answers to questions on condition of underground water mains

PLACE	MILES	AGE OF OLDEST PIPE	CONDITION
New London, Conn....	70	43	Cast iron; fair; 20 miles wrought iron removed because of improper coating
Steubenville, Ohio.....	30	70	Tuberculated; good after fifty years; small pipes abandoned because of corrosion
Boston, Mass.....	826	66	Corrosion ½ to 1 inch; some abandoned on account of salt marsh fill
Elgin, Ill.....	70	27	Good as when laid
Champaign, Ill.....		30	Good. No pitting inside or out
Philadelphia, Pa.....	1800	94	Iron corrosion inside;—outside good
Waltham, Mass.....	54	25	Excellent condition; no pitting inside or out
Spokane, Wash.....	359	30	Steel; thirty years; good. Cast iron, good. Wood, 12 years. Cast iron and steel about same. Wood bands gone, wood rotten
Rochester, N. Y.....	420	41	Good
Las Vegas, N. Y.....	23	35	Cast iron slightly rusted outside due to alkali soil. Steel and wrought iron rusted out
Omaha, Neb.....	297	35	Electrolysis in 1200 feet; 6 inch
Peru, Ind.....	35	41	Excellent inside and outside
Bangor, Me.....	55	38	Excellent inside and outside
Cincinnati, Ohio.....	714	70	Cast iron incrusted inside; outside fair
Pawtucket, R. I.....	192	38	Replaced with larger size; slightly tuberculated; outside good
Keene, N. H.....	47	39	Replaced by larger size. Cast iron good. Wrought iron poor, cement lined on account of breaks
Hudson, N. Y.....	30	42	Some pittings on outside. Wood and cement-lined replaced because not strong enough
Kalamazoo, Mich.....	90	45	Good inside and outside
Fort Wayne, Ind.....	140	32	Good inside and outside except pitting in cinder fill and some electrolysis
Memphis, Tenn.....	265	40	Good
Buffalo, N. Y.....	580	65	Good
New Britain, Conn.....	90	35	Some pitting in inside smaller mains. Outside pitting in cinders. Cement lines abandoned
Meadville, Pa.....	35	40	Good. Some pitting in cinder fill
Streator, Ill.....	47	28	Good, Some electrolysis

TABLE 2—*Continued*

PLACE	MILES	AGE OF OLDEST PIPE	CONDITION
		years	
Lancaster, Pa.	71	79	Good
Danvers, Mass.	60	20	Cement-lined, laid in 1876 given out, especially in smaller sizes. Cast iron tuberculated inside
Peekskill, N. Y.		40	Good
Davenport, Iowa	94	41	Good
Marshalltown, Iowa	40	40	Good
Hartford, Conn.	183	60	Good. Cement-lined failed and replaced with cast iron
Milwaukee, Wis.	517	43	Good as new after forty years
Detroit, Mich.	917	60	Good
Schenectady, N. Y.	113	30	Good
Marquette, Mich.	26	44	Slight incrustation inside, outside clean and bright
Montgomery, Ala.	105	35	Good inside and outside
Fort Wayne, Ind.	46	28	Excellent
Galveston, Texas	73	29	Good
Washington, D. C.	591	57	Inside tuberculated. Outside good, except in ash fill and some of the old horizontal-cast pipes replaced.
Ogdensburg, N. Y.	30	25	Some cement-lined pipe forty-six years old, still in use. Cast iron good except where laid in peat bogs
Lafayette, Ind.	56	39	Perfectly good inside and out
St. Louis, Mo.	975	50	Some tuberculation inside. Pitting outside in some places where there is damp yellow clay
Evansville, Ind.	120	42	Tuberculation inside but no pitting inside or outside
New Orleans, La.	570	5	Good
Stockton, Cal.	40	35	Good. Adobe soil affects outside some
San Jose, Cal.	160	47	Inside good, outside some pitted due to alkali soil
Seattle, Wash.	584	35	Cast iron good. Kalamein good. Some wood and spiral-weld pipe removed
Madison, Wis.	86	30	Good inside and outside, except in marshy soil filled with ashes and rubbish; 1000 feet replaced account of electrolysis
Holland, Mich.	29	19	Good
Middletown, Conn.	38	32	Inside tuberculated. Outside clean. Cement-lined replaced

TABLE 2—*Concluded*

PLACE	MILES	AGE OF OLDEST PIPE	CONDITION
		years	
Newburgh, N. Y.....	48	61	Tuberculated inside, outside good
Battle Creek, Mich....	73	28	Inside good; outside good, except few places where laid in swampy clay; 2000 feet 6 inch wood pipe in use still, laid 30 years
Cumberland, Md.....	40	30	Inside fair, outside good
Dubuque, Iowa.....	57	55	Cast iron, good
Quincy Ill.....	72	40	Cast iron, good inside and out
Johnstown, Pa.....	113	48	Good; some outside pitting due to acid soil
Charleston, S. C.....			Good
Bridgeport, Conn.....	220	35	Tuberculated inside. Outside good. Some electrolysis.
Providence, R. I.....	415	45	Some tuberculation. Outside good except in heavy damp soils
Portland, Ore.....	543	60	Cast iron good. Some pitting in steel pipe. Some wrought iron and wood abandoned.
Cambridge, Mass.....	138	58	Inside tuberculated. Outside good, some electrolysis. Cement-lined removed
Poughkeepsie, N. Y....	44	43	Good except where laid in ashes
Atlanta, Ga.....	353	38	Inside tuberculated. Good except in isolated places
Council Bluffs, Iowa...	60	33	Cast iron incrusted inside, good outside
Terre Haute, Ind.....	96	42	Cast iron, good inside and out; 24 feet removed, electrolysis
Lowell, Mass.....	150	40	Good as new

Besides the iron corrosion, various deposits are found in mains which are due either to sedimentation or the settling of lime in the water after treatment for softening or the deposit of limestone, such as is found in Salt Lake City, Utah, or the deposit of mud, or the deposit of red mud due to the presence of free iron in some waters, particularly ground waters. These deposits take place in many different forms. The red mud deposits all around the pipe in a wavy surface which retards the flow very much. Then there is a clay deposit, such as that found from the Big Muddy River in southern Illinois, where the clay mud deposits all around the pipe concentrically, in one case to the extent of cutting down an 8-inch pipe

to an open area of 5 inches. The surface of this also was wavy, further reducing the carrying capacity of that pipe. Then there are the waters which deposit mud in the bottom of the pipe, sometimes filling mains to more than one-half their diameter. This form of sedimentation is found in almost every part of the United States where turbid waters are pumped.

The results of a number of tests are submitted herewith, Table 3, showing the approximate number of years pipes in various localities have been down, the kinds of water passing through them and the percentage of carrying capacity lost on account of this corrosion. These tests, while not numerous enough to form the basis for definite conclusions, may perhaps be of use to the superintendent in determining what his conditions and his troubles may come from. Many tables of the flow of water in cast iron pipes give a coefficient to use for pipe a certain number of years old. These coefficients are so variable that it seems better to find out what the local conditions are for each particular place before deciding what a pipe will carry after being a certain number of years in service. Some comparatively hard waters, such as that of the Great Lakes, for instance, may flow through cast iron pipe for twenty years without seriously affecting the carrying capacity, while the waters of the Ohio River almost invariably reduce the carrying capacity to a very large extent in that length of time. In New England the surface waters in general will probably reduce the carrying capacity of small mains from 25 to 40 per cent in twenty years. Some of the snow waters of the Pacific Coast have reduced the carrying capacity of cast iron pipe to the extent of 50 per cent in twenty years. Some of the Southern surface waters which are very soft and in some cases contain organic acids have been known to reduce by 75 to 80 per cent the carrying capacity of small mains in a period of twenty years. The upper Mississippi, which at times runs very high in hardness seems to affect pipe but very slightly, except where the water has been softened, thereby causing a heavy rough deposit of lime. This is more or less true also of the Missouri River or Central Plains waters. Then there is the Arkansas River water, which runs very high in salt as well as alkalinity, and in the small pipes carrying this water there is frequently a reduction of 50 to 60 per cent in the carrying capacity in a period of twenty years.

To give the superintendent an idea of the effect of corrosion on 6-

TABLE 3

Loss in capacity of cast-iron pipe

LOCALITY	KIND OF WATER	SIZE	AGE OF PIPE	CAPACITY LOST	SPECIAL CONDITIONS
		inches	*years*	*per cent*	
South Milwaukee, Wis.	Lake Michigan	10	15	18	Hardness, 180–200
Chicago, Ill.	Lake Michigan	6	30	32	Hardness, 180–200
Rochester, N. Y.	Lake fed by springs	4	25	25	Spring water
New Jersey	Ground	6	30	34	Iron deposit
Missouri	Mississippi and Missouri Rivers	20	21	50	Lime and iron treatment
Rochester, N. Y.	Genesee River	12	28	52	Surface water
Lockport, N. Y.	Erie Canal	6	20	54	Polluted with sewage
Salt Lake City, Utah	Mountain water	6 16	20–25	50–65	Hardness very high
Camden, N. J.	Ground water	8	55	60	
Philadelphia, Pa.	Surface water	6	70	56	Hardness, 180
Cumberland, Md.	Potomac River	6	26	50	Hardness, 100–120
California	Mountain snows	16	18	50	Very soft
Meridian, Miss.	Surface and spring	16		50	Soft, sometimes acid
Madison, Ind.	Ohio River	6	25	60	Soft and sediment
New York	Surface water		31	70	Soft water
Kansas	Missouri River	10	28	62	Treated with lime; hardness, 300–450
Kansas	Missouri River	24	21	44	
Mt. Vernon, Ill.	Surface water	6	18	75	Manganese present
Arkansas	Arkansas River	6	20	78	High in salt and hardness
Missouri	Ground water	4	20	80	Sulphur and other minerals
Philadelphia, Pa.	Surface water	6	70	56	Hardness, 180

Huntington, W. Va	Ohio River	6	20	75	Soft; mineral acids
Wheeling, W. Va	Ohio River	6	20	80	Soft; mineral acids
Illinois	Surface water	6	31	70	Soft water
Long Island	Ground water	12	50	80	Soft
Boston, Mass	Surface water	16	59	47	Soft water
St. Louis, Mo	River water	6	25	63	Treated water
Meriden, Conn	Surface water	12		49	Soft
Connecticut	Surface water	36	25	32	Soft

NOTE: The percentage of carrying capacity lost in large pipes is not as great as that in small pipes, due principally to the fact the percentage of area filled by corrosion in the large pipes is not as great as that in the small pipes.

to 12-inch mains, so that he may judge of his local conditions by noting the interior of his mains when cuts are made, the following estimates are made:

Tubercules from $\frac{1}{8}$ to $\frac{1}{4}$ inch in depth, occurring principally at the bottom of the interior surface of the pipe, will cut the carrying capacity from 15 to 20 per cent.

Tubercules from $\frac{1}{8}$ to $\frac{3}{8}$ inch in depth, covering practically the entire inner surface of the pipe, will cut the carrying capacity from 35 to 40 per cent.

Tubercules from $\frac{1}{4}$ to $\frac{1}{2}$ inch in depth, covering the entire inner surface of the pipe, will cut the carrying capacity from 45 to 50 per cent.

Tubercules from $\frac{1}{2}$ to 1 inch in depth all around the inner surface of the pipe will cut the carrying capacity down from 70 to 75 per cent.

To determine the effect of this corrosion on the pipe some 25 samples altogether have been analyzed to ascertain the exact amount of the iron from the pipe which has been destroyed. In the worst samples, the rate of destruction is only about 0.1 per cent per year, or 10 per cent of the iron in 100 years. In some isolated cases, underneath these tubercules, there is a slight pitting, but even though the pipes are scraped, some scale is left covering this pitting and forms more or less of a protective coating to the iron at that point. As a very large factor of safety is used in designing cast iron pipe this pitting could be many times as bad as it has been in any place so far observed without seriously endangering the strength of the pipe. Many have seen samples of old Scotch pipe which was cast on its side, which had less than $\frac{1}{8}$ inch of metal, and this thin metal has stood the test of fifty and sixty years service. An example was found in Boston where there was only about $\frac{1}{16}$ inch of metal, and a very light tap with a chisel broke into the pipe. This pipe had been in service more than fifty years and there had never been a break in the line. Cast iron pipe has been in use in France for nearly two hundred and fifty years. Samples of pipe in Philadelphia, in service ninety-eight years, show an excellent condition of the metal, even though an analysis indicates the presence in the iron of elements and compounds that the present-day foundry would not have in a piece of its pipe.

DISCUSSION

A. F. KIRSTEIN: The speaker has adopted the plan, when making repairs, of backfilling the lower half of the trench with soft mud and the upper half with ashes. Has the author any information to show whether this will injure the pipe?

J. N. CHESTER: In western Pennsylvania there is considerable slag and refuse from coal mines in the ground at places. Whether a pipe laid as Mr. Kirstein describes will be injured will depend upon whether the leaching from the cinders reaches the pipe, or whether the cinders themselves will do as much harm as the leaching. If acid is formed from the cinders and reaches the pipe, damage is bound to be done.

With regard to the author's statement that tuberculation is about the only depreciation that need be counted on in cast-iron pipe protected from cinders and electrolysis, tuberculation will vary with the kind and quality of water that the pipes carry. Some who have used lime and iron as coagulant have found that they depreciated pipes very rapidly. When hypochlorite is used in water without filtration its effects will be apparent in the tuberculation of the pipe. Acid waters in mining districts act as tuberculators, and all know the effect of turbid waters. The use of lime and iron as a means of precipitating the turbidity of our western river waters without filtration may cause severe tuberculation. With filtration there is no harmful effect.

The speaker's experience is that small pipe tuberculates much faster than larger pipe. It was attributed for a while to the velocity, but at Little Rock, Ark., where a 4-inch pipe was run around from a 16-inch pipe and back into it, the 16-inch pipe being a discharge main, there was no reason to believe that the same velocity was not maintained in each pipe, and yet the 4-inch pipe was almost stopped up by tuberculation, and the 16-inch was hardly tuberculated at all. Observations subsequent to that time, which was twelve years ago. indicate that almost without exception a 4-inch pipe will show far greater tuberculation than a 16-inch. Ordinarily large lines are through lines, and naturally have higher velocities because they are not subject to dead ends; they are carrying water to the smaller mains, and velocities are generally higher in the larger than in the smaller mains.

GEORGE A. MAIN: The speaker will be interested to know the author's estimate of the proportion of the frictional loss due to the increased velocity made necessary by the reduced cross-section, and the proportion of the frictional loss due to the tuberculation.

With regard to the greater tuberculation and precipitation in small pipes as compared with large pipes, the speaker has found that there will be more lime precipitated from the softened water of Daytona in a $\frac{5}{8}$-inch goose neck than in the $\frac{3}{4}$-inch pipe forming part of the same service, although both carry the same amount of wate . The following explanation of this, and of the greater precipitation in small than in large pipes is offered: The eddy currents produced near the surface of the small pipes bring practically all particles of water into contact with the surface of the pipe. In the larger mains, the eddy currents are probably smaller in proportion to the diameter of the pipe, and therefore considerable water flowing near the axis of the pipe would come in contact with the metal much less frequently than in a small pipe. With a given velocity of flow there would be much more precipitation where all the water has a chance to reach the surface of the pipe.

RUDOLPH HERING: The effect of the roughness of the surface of a conduit on the flow of water through it was well shown by some of the celebrated experiments of Darcy and Bazin. One of their tests concerned two lines, each several hundred feet long, with semi-circular channels 1 meter in diameter. One was lined with rough rubble masonry; the other was lined with cement made perfectly smooth. They found that the quantity of water passing through the smooth cement-lined channel of the same sectional area and scope was just about twice that which went through the channel having the rough rubble surface. The 50 per cent loss was due to nothing else but the increased roughness.

Has not the quality of the material more to do with this question of tuberculation and roughness than the size of the pipe? The speaker recalls some celebrated experiments made years ago in the Whortley Iron Works, near Edinburgh, Scotland, by Andrews, who found that the quality of the material had a great deal to do with the tuberculation, caused by the formation of a battery, as it were, by pure iron, uncombined carbon, and the acid character of the water. The slightly acidulated water caused the electrical action. Those experiments, published in England about thirty years ago,

very clearly indicated that the presence of uncombined carbon in wrought and cast iron was the chief cause of rust. Therefore, in San Francisco, the engineer of the Spring Valley Water Company, Mr. Schussler, desiring to use iron pipe at a time when it was very expensive to get iron pipe on the Pacific Coast, thought that he might use wrought-iron for his pipe; and as he had in mind the experiments made at the Whortley Iron Works, his specifications called for iron from which the uncombined carbon had been almost entirely removed by repeated rolling. The speaker saw some of those pipes after some years' use, and he was surprised at their condition. There was hardly any rust on the surface after many months' exposure to air and rain. Therefore he thinks the uncombined carbon that is generally found in cast-iron may have a good deal to do with the tuberculation of iron pipes.

CHARLES F. BARRETT: On 1915, an examination of a number of water mains in Salt Lake City showed that they were carrying only 36 to 65 per cent of the quantity of water they should deliver. They were then cleaned and the discharge through them tested. These tests showed that the average discharging capacity of the cleaned mains was about 99 per cent of the theoretical capacity. An analysis by the state chemist of the scale removed by the cleaning operations showed that it was composed of 90 per cent of calcium carbonate, 5 per cent of silica, 3 per cent of iron and alumina, and 2 per cent of magnesia.

E. E. DAVIS: The speaker has taken up a great deal of pipe laid in the forties, and found it the worst pipe he ever had experience with. He has taken up 4-inch pipe that showed what were then called "rust bubbles" but are now called "tubercles." An old waterworks man told the speaker that this badly tuberculated pipe laid in the forties was made at blast furnaces and not in foundries; in other words, they did not run the iron into pigs but the pipes were cast at the furnace. In those days the makers did not have to conform to any specification as to quality. There was some old pipe in which it was impossible to cut a hole with a diamond, yet it became tuberculated.

In Richmond not much trouble is experienced with anything except James River mud. Since sulphate of alumina has been used as a coagulant, instead of the mud inside the pipes becoming very hard

it has a consistency like that of vaseline. Formerly when there was a fire it was difficult to obtain a good stream out of a pipe because of that mud, until the hydrant was allowed to flow for a while and the mud was flushed out.

LEONARD METCALF: The discussion might be directed to one or two points of importance in their bearing upon valuation of water works.

First, you are urged to do everything that you can to keep your records clear and to keep good records of the actual cost of your work as you go along. That is coming to be a matter of greater importance in valuation and rating problems as time goes on. As an example of the effect of information of that sort, there may be cited the recent valuation of the Indianapolis Water Company, the rates of which were under question. The cast-iron pipe records were in very fair shape from the earliest days of the company down to date. The greater part of the purchases had been made in the last twenty years, so that they had a far greater influence on total cost of pipe than the earlier purchases, though the earlier purchases had been at much higher rates; but after a study of the cost of the pipe and actual purchases by that company, and by other companies in that vicinity, it was concluded that the ten-year average was approximately $24 per ton of 2000 pounds; that the five-year average was approximately $1.50 per ton less than that amount; but that the actual cost of all the pipe purchased in the life history of the plant was approximately $25.90 per ton. Therefore, it was suggested to the Commission that in all fairness to the company and justice to the community, the five-year average which had sometimes been used in such cases was not a fair one to use, nor did the ten-year average in this case do full justice to the facts, particularly as an era or a period of high prices is here. Inasmuch as there could be no doubt that the average price for the succeeding or coming ten years will doubtless be higher than for the past ten years, it would certainly be fairer to use a figure more nearly approaching, if it did not equal, the actual cost of the pipe to the company. Therefore, in this case the importance of the record to the company is clear.

It is also of importance to know the exact source of data. It has been very common to use quotations from trade journals; if no better information is available, these may be of value, but if the records of actual prices paid within the decades covered by the records are compared with these quotations, considerable divergencies will ap-

pear even though a comparison of the prices paid by neighboring cities for the pipe show fairly consistent and similar results. The statement which one sometimes hears, that pipe is not bought in the years of high prices and that therefore less weight should attach to the years of high prices than to the years of low prices, is not borne out by the history of existing plants generally. A study of such records shows cases of which that can be said, and many cases of which it cannot be said. The speaker does not feel that the data which he has, though they cover the experience o a number of works, are broad enough to determine the average condition. In comparing the prices of pipes bought by seven or eight cities, as many cities were found to have bought pipe at the higher prices as had bought it at the generally lower prices, which simply illustrates what all know, that when the need is urgent mains must be laid regardless of the price of pipe.

With regard to the carrying capacity of mains, it is frequently found, particularly with waters carrying more, rather than less, organic matter, that a pipe line in proximity to reservoirs will show greater frictional loss or resistance, particularly when the source of supply is from a river or lake, than elsewhere in the pipe system, owing to incrusting organic material and slime or sponge. The speaker has seen sponges one-half of a square foot in area and 2 or 3 inches in length in some penstocks and pipe lines and living aquaria inside of these pipe lines in proximity to the reservoirs or sources of supply.

The progressive deterioration in any good pipe line is difficult to determine from inspection or measurement. The most accurate and helpful way to determine it is to make experiments and keep records of the increasing frictional resistance to flow in the pipe line from year to year. The speaker had a very interesting experience a few years ago in going through a number of wrought-iron and steel pipe lines. Among them was a pipe of the New Bedford Water Works, inspected with Thaddeus Merriman, of the New York board of water supply, who had been through this same pipe and taken micrometer measurements of the pitting about five years before. It was hoped to obtain suggestive ideas from that comparative experience; and quite a large number of measurements of the length of the tubercles and blisters and pitting were made. This pipe line was of steel and not of cast-iron; but the same thing might be said of a cast-iron pipe line. The pipe line was entered at a number of points and traversed through several hundred feet, in the aggregate, of its

length. Mr. Merriman stated that he could not see that a comparison of his earlier and later records showed any substantial difference; whereas the pumping station records did show some difference.

The Pitometer Company has, in the course of its experience, made some exceedingly interesting studies of pipe lines in this country. The speaker remembers one such, reported at Denver, where the plant was being valued. Some approximate experiments had been made with more or less crude apparatus to determine the friction loss of the lines. The results were higher than expected, and it seemed wise to have more precise measurements made. The Pitometer Company was called upon to assist; and in order to get as useful information as possible, pipe lines of varying ages, varying from a decade or more, were selected and gagings were made in the hope of being able to determine the progressive deterioration in carrying capacity. The data are quite interesting, and will be valuable when placed side by side with other similar records. Of course they cannot be directly applied to any other condition, particularly as it was clear that the waters of that region, perhaps due to their magnesia content, had resulted in a greater roughening of the surface, or sufficient roughening of the surface, to account for the difference in carrying capacity, although this was not always apparent to the eye. Dr. Hering has already called attention to the fact that a very slight apparent difference in the character of the surface may bring about a very marked difference in carrying capacity.

The speaker's experience has been the same as Mr. Chester's, that with pipe of like ages it is found that when the coefficient for the Hazen-Williams formula for a certain age is, let us say, 80 for small pipe, for a large pipe of like age the coefficient will be 90 or 100, or more; in other words, that the same reduction in carrying capacity does not result in the larger pipe, although the apparent interior condition of the pipe does not differ so markedly that the difference can be distinguished by eye.

The speaker has been through hundreds of feet of the Spring Valley Water Company's pipe, in and near San Francisco, which was referred to by Dr. Hering, which has made a most remarkable record for itself. The record was due partly to the excellent surface coating developed by Mr. Schussler which has shown remarkable properties after forty-seven years' use. Pipes were traversed that had been down twenty-five or thirty years and the coating was found almost perfect. While it appeared fairly hard it could be dented

with the thumb-nail. Placing the thumb on it and working it gradually from side to side softened the coating enough to flow; yet it has been hard enough to keep its shape. Allen Hazen and the speaker went through 700 feet of another pipe line 44 inches in diameter, and there were only one or two blisters in each length of 3 feet or so, which shows in what a remarkable state of preservation that pipe line is.

With regard to Mr. Davis's statements about the tuberculation of old cast-iron pipe, it is probable that while some part of the improved carrying capacity of recent pipe may be due to better metal and better foundry practice, most of it is to be attributed to the pipe coating. A large part of the old cast-iron pipe was uncoated, and its quality varied greatly.

F. N. CONNET: Tuberculation seems to be quite distinct from incrustation and is more apt to occur with soft than with hard waters. In cross-section a true tubercle is built up of a series of thin layers like an onion and the speaker believes that two layers per year are usually deposited. Since the growth of crenothrix also occurs twice a year, the question arises whether the tubercle may not be the remains of successive growths of this organism. The metallic iron underneath the tubercle is usually dissolved out in the shape of an inverted cone leaving the uncombined carbon unaltered and intact, but this latter can be easily cut out with a pen knife.

The speaker has observed the tendency of tubercles to collect near brass fittings, which suggests electrolytic action also. May not the crenothrix, because of its iron content, be deposited electrolytically upon the tubercle, thus causing it to grow indefinitely? In other words, may not a tubercle be in reality a graveyard of many generations of crenothrix?

B. B. HODGMAN: In discussing old records of prices of pipe it is important to keep in mind the ton used in each case as the unit of quantity. At Providence, R. I., for instance, pipe was bought by the long ton down to 1905. In comparing prices over a long range of years, the selling price may be found to have been affected at times, in a measure, by the currency conditions, which some persons consider were influential in fixing prices from 1868 to 1873.

Where pipe lines are covered by a foot or more of earth which is covered in turn by cinders, the author has never discovered that water percolating down through such backfilling injured the pipe.

The tuberculation of pipes as actually found during testing and cleaning operations presents many interesting features. For instance, in recent tests of a 24-inch main and a 10-inch main laid at about the same date, the larger pipe was found to be carrying considerably over 50 per cent of its rated capacity when new and the smaller pipe about 40 per cent. In Lockport, N. Y., it was found that the carrying capacity in a 6-inch main in a busy part of the city was only 40 per cent of that of new pipe, but farther along, where there was a much lower velocity through the main, the capacity was 90 per cent of that of new pipe. It has been observed that the number of taps in a main has a decided influence on the deterioration in its carrying capacity. For instance, 2000 feet of 8-inch pipe without taps, tested in New Haven, Conn., showed a much smaller loss of capacity than was found in the next 2000 feet, where there were taps for a house on each side of the street every 50 feet or so. As a rule, it is found that there is more tuberculation in a line with taps than in one without them. The reduction in area by tuberculation is, of course, proportionally greater with small than large pipes. Half an inch of incrustation on the inside of a 4-inch main reduces its area about 45 per cent, whereas half an inch of incrustation on a 16-inch main reduces its area only 7 per cent. It is this decrease in effective area of a pipe which is responsible for a considerable part of the difference in its carrying capacity; the decrease should not be attributed exclusively to increased frictional resistance due to tuberculation.

SOME FEATURES IN ARTESIAN WELL CONSTRUCTION IN MANKATO[1]

By H. F. Blomquist

Mankato is located in the artesian basin of Minnesota, being in the southwestern part of it, and a number of artesian wells have been sunk in the city. The first was sunk in 1888. One of the deepest wells in the United States is located only 1½ miles from here. The hills around Mankato are about 230 feet above the street level and the city wanted a well upon the top of one of these hills, called Bunker Hill, one of the highest in the city. A well was drilled about 2204 feet deep and was at that time one of the deepest, if not the deepest, in this country. The water rose within about 40 feet from the surface. That would bring the water approximately 175 feet above the elevation of the business section of the city. It was intended to run that water into a reservoir but the plan did not work out as well as anticipated. The city spent $12,000 in the experiment but the well has never been used. An artesian well was sunk in this city about two years ago that is 1452 feet deep.

One of the first wells that was drilled was about 365 feet deep. Two others were sunk about 665 feet each and gave the required supply of water. In 1900 one of those wells was deepened to 1365 feet to increase the flow of that well. The flow then was over 600 gallons a minute, flowing at the surface of the ground. That was sufficient until more wells were dug, particularly one by the Hubbard Milling Company. The one deepened to 1365 feet was again deepened last summer to 1450 feet, and given an iron casing to a depth of 220 feet. Steel casing lasts about twelve or fifteen years. It has been necessary to replace the casings of two wells within the last three years. A bad feature is that when the casing starts to leak it is necessary to put in a smaller casing, thereby reducing the size of the well. In the last well that was built, a cast iron casing was used, A 16-inch hole was drilled and a 15-inch pipe was lowered about 90 feet. A 15-inch hole was continued to 156 feet. Cast iron pipe

[1] Abstract of a paper read before the Minnesota Section, November 10, 1917.

was made expressly for this well, threaded at the ends and coupled together with brass couplings, and it is hoped the well will stand about fifty years more.

The water here contains a certain amount of substances that are not wanted and some kind of purification is desirable. There are some peculiarities in the water not found in the ordinary well supplies. The artesian water comes from the depths where the pressure is very high, and since water under high pressure holds substances in solution which would otherwise be in solid form, the water of Mankato contains matter in solution which is afterwards precipitated when the pressure is relieved. Evidence of this is often seen when water is drawn from a faucet into a glass. The water containing carbon dioxide in solution under pressure holds iron and sulphur compounds in solution, which, when the pressure is relieved and the water comes into contact with air, undergo chemical reactions which change the iron compound to ferric hydroxide which precipitates into a brown substance, and is so often seen when water is allowed to run slowly over a light colored surface. The sulphur is given off in the form of hydrogen sulphide, which has the peculiar odor that is responsible for the erroneous assumptions of some consumers that the water has become stagnant in the mains. The carbon dioxide is also given off when the pressure is relieved, and being a gas it forms in small particles and gives to the water a milky or turbid appearance often seen when filling a glass, but which soon passes off leaving the water clear. Because of this quality of the water it is necessary to flush the water mains very often.

THE PROBLEMS OF A SMALL WATER WORKS PLANT FROM THE MANAGER'S STANDPOINT[1]

By T. C. Gordon

The electric power plant and water system at Little Falls, Minn., are both owned and operated by the same company. The power is generated from falls in the river. The two public utilities are housed in the same building and the same men operate both. Water is pumped directly into the main from the Mississippi River, there being no storage reservoir or filtration system, and there are no auxiliary fire pumps.

There are two pumps having a maximum discharge of 2,225,000 gallons and this is taxed during fires of any great extent. The author is not familiar with what other towns of similar size (7000) are doing, but he knows that with the pumps and a fire pressure of 125 pounds it is hard to get a satisfactory pressure a mile or more away from the station. None of the mains are less than 6-inch and in all of the business section they are 8 and 10 inches.

The pumping station is three-quarters of a mile from the business district. When it is necessary to repair the main feeder, all preliminary work is carried out as far as possible before midnight, when the pump pressure is reduced or the pumps shut down entirely if necessary, while the leak is repaired. Repairs to laterals are made behind closed valves, of which there is a liberal supply. There are only three dead ends in the system. Repairs with lead wool were tried but the work was not satisfactory so that lead and oakum were again used. The company does not care to experiment with new ideas if old methods are satisfactory.

In the town the service from the main to the curb is owned by the property owner, but when a leak appears the company is advised that its main is broken and usually has to make the repairs, but only occasionally is it repaid. The company taps its mains and furnishes the corporation cock. As a general thing the sewer and water pipe are laid in the same ditch, the sewer, of course, being much lower than the water service.

[1] Abstract of paper read before the Minnesota Section, November 10, 1917.

All mains are laid 8½ feet below street grade. Frost troubles are confined to services, which are thawed out with electric current using a 10-kilowatt transformer mounted on a wagon with connection to a hydrant and to a service pipe inside the premises. A 50-volt tap on the transformer is used, thereby getting a heavier flow of current. A frozen service is thawed out in less than five minutes. Last winter many services froze which had not frozen in previous years. Fire hydrants are closely watched and steamed out with a portable steamer. Hydrants are inspected after every fire to see that they have drained properly. A great deal of trouble has been experienced with roots plugging up the drain on fire hydrants.

When the system was installed (1890) the contract provided that a supply of pure and wholesome water should be provided taken from the Mississippi River. It was then generally taken for granted and understood that flowing water purified itself in every 15 or 20 miles of travel. The company went along on this theory for several years and must have pumped out of the river millions of germs but without any typhoid outbreak. It installed one of the first hypochlorite plants in the state, much to the disgust of the station operators who had to look after it. As soon as the liquid chlorine method of purification was effected the company tore out the chloride plant and installed the liquid chlorine. From the standpoint of continuity of service the chlorine system is not entirely satisfactory. Parts will get out of order and cause shut-downs, but any shut-down means the pumping of impure water and this of course is something that must be avoided.

An auxiliary pumping plant is to be located within three blocks of the business center. The new unit will be motor-driven with a remote control switch at the present pumping station, and will be used especially for fire protection and in time of trouble at the main plant. It is also planned to install a filtration plant and a standpipe with motor-driven pumps to operate at off-peak periods, These improvements are awaiting an easier market.

ADVANTAGES OF A LOCAL SECTION OF THE AMERICAN WATER WORKS ASSOCIATION[1]

By F. W. Cappelen

The Minnesota section has 34 members and is the smallest of all the sections now formed. By states, including Canada, Minnesota stands eleventh in number of members; 25 of the 34 members reside in Minneapolis, St. Paul and Duluth leaving only 9 members scattered around the state. There is a splendid opportunity for campaigning for members among the small city water works officials in Minnesota. We need the smaller water works men for their good and ours.

Quoting from the speech of President Metcalf at the Richmond convention,

> We should strive to reach and serve the general practitioner, the practically trained man, rather than the highly educated or technical one occupying highly specialized position, to give this large class of capable men the opportunity not only to get together in annual convention, but to assist in developing and advancing the state of art in their particular fields of activity.
>
> The local organizations in any profession or calling have an advantage over those of national membership, in that they afford greater opportunities for personal touch and discussion.

This statement by Mr. Metcalf hits the nail squarely on the head. Have you really considered the tremendous importance of our position, that of furnishing pure, wholesome water for all the people?

Those using chemicals in the purification of water probably know. the difficulties encountered in obtaining such supplies. The author has been obliged to take up the matter of car service for the Minneapolis Water Works with the Board of National Defense. His argument for preferential car service was this: Assume we could not get service and would have to supply impure water to 400,000 people, and cause, may be, a typhoid fever epidemic with a death rate as bad as the war itself, what shall the water department do? This suggestion worked. Minneapolis was assured car service. It can be readily seen how the section can be put to work, and the more members, plant members, we get, the more influence the section will have. There are in Minnesota 271 domestic, and 16 privately owned water plants besides 264 privately owned well supplies.

[1] Read before the Minnesota Section, November 10, 1917; abstract furnished by Section Secretary.

NOTES ON THE PRESUMPTIVE TEST FOR B. COLI[1]

By Max Levine

Examinations of waters for B. coli constitute an important part of the tests employed for the control of water supplies. Isolation and complete identification of the organisms is too laborious and costly for routine work and it is therefore desirable to have some simple test by which the probable presence of B. coli may be quickly determined with a sufficiently high degree of reliability to give a reasonably accurate idea of the existence of pollution.

The ideal medium for such a presumptive test would be one in which B. coli flourishes while other forms are inhibited, but this ideal has not as yet been attained. The requirements of a reliable presumptive test may be briefly stated as follows:

1. The medium employed must be one in which a test characteristic of B. coli is quickly obtained and easily recognized.
2. The medium should not inhibit the growth of B. coli nor permit its overgrowth by such forms as B. aerogenes.
3. Anaerobic spore-forming gas producers should be inhibited or some simple supplementary test provided by which errors due to their presence may be eliminated.
4. It is desirable that the test should also differentiate between true B. coli and B. aerogenes.

Until 1906, the most commonly employed presumptive test was gas production in dextrose broth. The formation of 25 to 70 per cent gas, of which approximately one-third was CO_2 was regarded as an excellent indication of the presence of B. coli and dangerous pollution. This criterion has been conclusively discredited. The variability of the gas ratio as determined in routine analysis, the many bacterial forms which ferment dextrose but not laxtose, coupled with the relatively greater incidence of such forms in treated and partially purified sources than in polluted waters, makes the old dextrose broth presumptive test an unreliable index of pollution. This is particularly true in warm weather.

[1] Read before the Iowa Section on October 10, 1917.

Since 1906 the most commonly employed presumptive test has been lactose peptone bile. The advantages over dextrose broth are many, but recently there has been a tendency to use lactose broth in order to eliminate the inhibitory action of bile.

Where pollution has been recent, the lactose bile or lactose broth presumptive tests are very reliable, but with relatively pure or treated waters, a positive presumptive test is not infrequently obtained when no B. coli are present. This confusion is due to the presence of spore-bearing anaerobic lactose fermenters. The error may be easily eliminated by plating from the positive lactose bile or broth tubes to some solid medium in petri dishes, as recommended by the U. S. Treasury Department Standard for drinking waters on common carriers.

The recent work of Rogers and his associates of the United States Department of Agriculture, which has been confirmed by many other investigators, has demonstrated conclusively that there is a marked correlation between certain types of coli-like bacteria and their sources. Two types may be easily distinguished; the B. coli which is constantly found in feces of man and in sewage but rarely in unpolluted soil, and the B. aerogenes which is rarely obtained from feces, but commonly found in cropped soil, on grains, etc. That these two types are very different in their sanitary significance is evident, since B. coli is characteristically of fecal origin whereas B. aerogenes is not. It is therefore desirable that they be differentiated in routine water analysis.

The following procedure is suggested as routine:

1. Plant portions of the sample in 0.5 per cent lactose peptone broth. Incubate at 37°C. for forty-eight hours.

2. After twenty-four hours incubation smear onto eosine methylene blue agar plates described below, from the highest dilution showing any gas (preferably also from the next highest dilution) and incubate at 37°C. for twenty-four hours.

If gas production is due to B. coli, characteristic black colonies with a metallic lustre will develop on the eosine-methylene blue agar in fifteen to twenty-four hours. B. aerogenes also grows well on this medium but its colonies are so distinctly different from B. coli as to be easily distinguished. Anaerobic spore-forming gas producers will, of course, not develop, thus eliminating the error introduced by their presence in the fermentation tubes.

Lactose broth. The new Standard Methods of Water Analysis of the American Public Health Association recommend 0.5 per cent peptone and 1 per cent lactose for the lactose broth medium, and incubation for forty-eight hours before any confirmatory tests are applied. With 1 per cent lactose, this period of incubation is too prolonged and detrimental to the successful isolation of B. coli. In a private communication Dr. Joseph Race of Ottawa, Canada, points out that beginning with equal quantities of B. coli and B. aerogenes there are found many times as many B. aerogenes as B. coli in 1 per cent lactose peptone bile-salt broth after forty-eight hours. The ratio may be as high as 18 to 1. The probability of obtaining B. coli from such a mixture by plating on litmus lactose agar is evidently slight.

In some unpublished studies in this laboratory it has been observed that with pure cultures of B. coli a maximum count is obtained in about twelve hours. In a medium with 1 per cent lactose B. coli begins to die off after twenty-four hours, some strains disappearing very rapidly whereas many B. aerogenes-like forms do not. If the quantity of lactose is reduced to 0.5 per cent, the death of B. coli is retarded considerably, and the probability of its detection thereby increased. One-half of one per cent lactose is sufficient for rapid and characteristic fermentation and this quantity therefore seems more desirable than the standard 1 per cent.

Eosine methylene blue agar. The agar medium recommended is a modification of that employed by Holt-Harris and Teague for the isolation of B. typhi, and is prepared as follows: Distilled water, 1000 cc.: agar, 15 grams: peptone (Difco), 10 grams: K_2HPO_4, 2 grams.

Boil until dissolved. Make up loss due to evaporation, and place measured quantities in flasks or bottles. Sterilize in autoclave for fifteen minutes at 15 pounds pressure.

Neither adjustment of the reaction nor filtration is necessary.

For use the following materials are added to each 100 cc. of the melted agar as prepared above: 1 gram or 5 cc. of the sterile 20 per cent lactose solution, 2 cc. of 2 per cent aqueous yellowish eosine, and 2 cc. of 0.5 per cent aqueous methylene blue. The aqueous solutions of the dies will keep in the ice box several months.

Differentiation of B. coli and B. aerogenes. On the eosine methylene blue agar as prepared above, B. coli forms characteristic button-like colonies 2 to 4 mm. in diameter with large black centers. There is

also a greenish metallic lustre and they are only slightly raised above the surface of the medium. B. aerogenes forms colonies which are much larger, considerably raised above the surface of the medium: characteristically show a relatively small brown center and the metallic lustre is rarely observed.

Of 122 colonies tentatively diagnosed as B. coli from their appearance on the agar, 97 per cent were B. coli, while of 102 colonies of supposed B. aerogenes 83 per cent were confirmed. The differentiation on this medium therefore seems reasonably reliable.

Conclusions. In the lactose broth presumptive test, 1 per cent lactose is detrimental to the successful isolation of B. coli, as many strains die off rapidly after twenty-four hours. A reduction of the lactose to 0.5 per cent reduces this error and is therefore recommended for routine tests.

For a rapid confirmatory test, the modified eosine methylene blue agar, because of its simplicity, ease of preparation, and the differentiation which it permits between B. coli and B. aerogenes, may advantageously be substituted for litmus lactose agar or the Endo medium, in routine water analysis.

The necessity for confirming the presumptive test and differentiating between the objectionable B. coli and the more widely distributed B. aerogenes and anaerobic gas-formers is not only of theoretical interest but of considerable practical significance when dealing with surface waters which are purified by sedimentation or chlorination. Where the positive presumptive test is due to spore formers, the amount of chlorine necessary to remove them is far in excess of that required to make the water safe. B. aerogenes also seems to be more resistant to treatment than B. coli. A knowledge of the type of bacteria responsible for a positive presumptive test thus becomes of practical significance.

LABOR SAVING MACHINERY[1]

By J. A. Jensen

A change from steam to electrical pumping reduces the number of men required for operation. One motor tender and an assistant replace the firemen, coal passers, boiler cleaners, engineers and oilers required for steam pumping. In filter plants much of the machinery is power operated and automatic, requiring only supervisory attention. Auxiliary electrically driven pumps for booster service are automatically controlled by float switches in the standpipes. They are visited occasionally by the engineer for the purpose of inspection and lubrication.

Labor-saving machinery is required more and more each year because of the growing scarcity of labor. Trenching machines for water pipe laying, auto trucks for transportation and other kinds of machinery for the handling of earth and materials are labor-saving devices.

In 1913 the city of Minneapolis purchased a large trenching machine for use on several miles of trunk pipe lines. This machine put out 39,200 cubic yards of earth at a unit cost of 9.3 cents per cubic yard on about 3 miles of trench. On another piece of work a steam shovel on back-fill handled 23,730 cubic yards on 9250 feet of trench at a unit cost of 4.8 cents per cubic yard.

On work in limestone ledge, trenching for pipe laying, an air compressor and operator with two plug drills and two men replaced twenty men with hand drills. In laying steel pipe the same compressor with ten boiler makers equipped with the necessary riveting and calking hammers, reaming tools and other equipment carried on the work of a whole company of similar skilled labor with hand tools.

A single first-class power operated trench pump has been found to do as much work as three hand-operated pumps manned by a dozen laborers.

[1] Abstract of paper before the Minnesota Section, November 10, 1917.

In service work with miscellaneous jobs scattered over 40 or more square miles of territory, Ford runabout trucks are employed, each rig and two men, generally speaking, replacing three single-horse rigs and six men. This is explained by the fact that the principal part of the performance in street service is mileage, and the work itself is secondary so far as time element is concerned.

METALIUM[1]

By Homer V. Knouse

The industrial progress of the United States has been due not only to the inherent enterprise of Americans, but almost equally to their readiness to put aside old methods and try new processes. This has been true particularly in connection with concentrated industries commanding large capital and corresponding profits. In such cases, under intelligent management, new ideas have been not only welcomed but experimental work encouraged notwithstanding the uncertainty of results and the expense involved, which in many instances has been enormous.

However, there are certain industrial processes that have been unaffected by this spirit of progress, that are utilized today just as they were fifty years, even a hundred or more years ago. Examples are those used here and there in construction work, mostly simple in character and while far from ideal, yet not unsatisfactory. Such processes have thus persisted largely as the result of habit, and the absence of the incentive of material financial gain, which alone seems capable in the industrial world of overcoming the inertia of habit and compelling the adoption of improved methods.

One of these unimproved processes is the use of lead for jointing bell-and-spigot water pipe. This practice was in vogue more than a century ago, and the method remains practically unchanged to this day, even to the use of a mud or clay roll as a joint runner, which still persists in many instances. It is true that lead makes a very satisfactory joint when properly run and calked, but the material and method are far from ideal. First, lead is relatively expensive, hence the loss from oxidation and scattering is material; also being readily saleable, it is subject to theft. Second, for melting, it requires a relatively high degree of heat, often resulting in over-heating and hence oxidation. Third, if not hot enough it cools before the joint is entirely filled, and, in spite of calking, the joint will ulti-

[1]Read before the Iowa Section on October 10, 1917.

mately leak. Fourth, its handling is not without danger because of its weight and the liability of explosion in case of wet joints. Fifth, a lead joint must be calked and the calking should be done by a reliable, skilled mechanic, otherwise a bell may be ruptured, and here and there the bottom of a joint neglected because of the difficulty of getting at it. Skilled calking is constantly growing more expensive, in some localities the wage demanded being as high as 55 cents per hour, with a limit on the number of the joints for a day's work. Unskilled calking means an unsatisfactory job, sooner or later. Sixth, calking requires the digging of bell holes which adds to the cost of excavation. Seventh a leak in a lead joint will persist; it will not decrease automatically but it increases with time.

In view of the shortcomings of the lead joint, the management of the Omaha water plant, some years ago, began seeking a substitute for lead, and as result, experimented with a metalloidal composition or alloy known as metalium. The advantages claimed for this material are the following:

1. Low cost. To compete with metalium as a joint filler lead would have to sell at approximately 2 to 2½ cents per pound.

2. Low melting temperature. This is a little more than one-third that of lead, resulting not only in a saving of fuel but also eliminating all danger from explosion in pouring a wet joint.

3. A relatively high specific heat. This insures with greater certainty the complete filling of a joint, and enables joints to be poured successfully at a considerable distance from the melting pot.

4. A low specific gravity. This is about one-fifth that of lead. Thus a man can easily handle a bucket of molten metalium sufficient to run a 48-inch joint.

5. No calking required. This eliminates the expense of calkers and the digging of bell-holes and also materially expedites the work of installing pipe lines.

6. The automatic closing of leaks developing in metalium joints. Initial leaks gradually close and those due to subsequent settlement of pipe eventually terminate likewise.

After a number of trials, it was concluded that these claims were substantially justified, and metalium has been utilized, to the exclusion of lead, in the installation of all pipe lines within the Metropolitan Water District for the past four years or more. In fact, a carload of lead purchased early in 1913 was subsequently sold at war prices, thereby netting the District a handsome profit.

Joints of all sizes of pipe have been run, from 3 inches to 48 inches in diameter, and during the period in question in the neighborhood of fifty miles of pipe lines have been installed in the Water District, subject to pressures as high as 115 pounds, using metalium alone as the jointing material. In the care of pipe of larger diameters than 24 inches, however, a bestolyte lining is inserted before the metalium is poured.

In view of these facts, it would seem that metalium should supplant lead in the installation of water mains under ordinary conditions, and that too, notwithstanding the inertia of habit, as the saving per mile of pipe in comparison with the use of lead, at 13 cents per pound (the quoted price of lead when these calculations were made) is approximately as follows:

Diameter of pipe, inches.....	6	12	24	48
Saving per mile.....	$565	$993	$2415	$5160

While metalium possesses a number of advantages over lead as a jointing material, yet its adoption entails one disadvantage that should be realized and understood by any one contemplating its use. This disadvantage consists in the initial leakage that often takes place in metalium joints when the water is first turned on. In a lead joint, this leakage is obviated by calking, while in the case of a metalium joint, the pressure is left on with the result that calking is accomplished automatically, it being simply a matter of time. This self-calking is not merely an accidental result, experience having demonstrated it to be positive and certain in character.

Although this disadvantage, therefore, is apparent rather than real, it can readily constitute a real obstacle to the adoption of metalium in the mind of one contemplating its use, due to the fear that such initial leaks will not close. However, experience soon dissipates this fear and begets full confidence, so that ultimately there is no hesitation to cover a pipe line as rapidly as joints are run, which is unvarying practice in the Metropolitan Water District.

The following test illustrates this self-calking quality: After a newly laid pipe line was filled, the valves at each end were closed, and the line supplied with water through a $\frac{5}{8}$ inch meter. The first reading indicated a leakage of 1790 gallons per mile in twenty-four hours per inch of diameter of pipe; two days later this leakage was 564 gallons; five days later it was 174 gallons; one day later 139 gallons; two days later 115 gallons; three days later 85 gallons, and at

COMPLETED METALIUM JOINT BEFORE THE GATE HAS BEEN BROKEN OFF

METALIUM FURNACE

LEAD FURNACE CONVERTED INTO METALIUM FURNACE BY REDUCING GRATE AREA TO AN 8-INCH CIRCLE

MELTING METALIUM OVER AN OPEN FIRE ON A SMALL JOB

a subsequent reading of the meter, the line was practically tight. In this connection it should be remembered that authorities are not wanting that decree a lead jointed pipe line tight when the leakage does not exceed 300 gallons upon the same basis of measurement. A mile of 24-inch pipe, which showed a considerable initial leakage when first put into service, was subsequently tested and found to be practically bottle tight.

Again, the accounting department of the Metropolitan Water District affords monthly statements of water passing through all consumers' meters, and these statements show that more than 83 per cent of the water supplied to the city of Omaha (Venturi meter measurement) is accounted for through such consumers' meters, and this notwithstanding the fact that there are still about 500 flat-rate services in use and some 600 sewer flush tanks unmetered. The estimated water used by these unmetered services, together with that used in building, for street flushing and sprinkling, the flushing of sewers and water pipe trenches, and the water required for fire service, is estimated at 5 per cent, thus making the total water accounted for 88 per cent of that supplied to the District. When it is remembered that some water systems cannot account for more than 60 per cent of the water supplied, it suggests that the mains of the Metropolitan Water District are reasonably tight.

Metalium is of a dark greyish luster, and is supplied commercially in globular form, put up in bags of 100 pounds each. In use, it is melted and poured just as in the case of lead. However, while the temperature of molten lead when poured is immaterial, in the case of metalium the temperature is important; it must not be too hot. It is not difficult to tell when metalium is ready to pour, as it is then a thin, nearly black, oily appearing liquid. If too hot, molten metalium is inclined to thicken and does not pour readily. The difficulty of firing the ordinary lead furnace so as to limit the temperature renders it unsuitable for metalium. However, if the grate area of such a furnace is choked down with fire brick and clay so as to leave the open surface but 8 inches in diameter, such a furnace can be utilized. But the best plan is to secure the specially designed metalium furnace, as it is light, cheap, and admirably arranged for temperature control. It is surprising the small amount of fuel required—either coal or wood. In the Water District work old discarded lumber is chopped up for this purpose.

Furnaces using oil or gasoline are also satisfactory but are difficult to keep going in a high wind. It is very important that the bell

and spigot of the joint to be run should be thoroughly clean and free from oil or grease. For this reason unoiled jute yarn, only, should be used for packing. Tarred yarn or yarn that is not free from oil or grease must be avoided. As a matter of fact, practically all initial joint leakage can be obviated if particular care is exercised in cleaning and keeping clean, each bell and spigot, using a putty knife to remove all lumps and blisters in the pipe coating. One of the Water District's most successful foremen does this, and after the joint is yarned, he inserts a loose strand of yarn so as to keep the joint free from dirt until poured, a practice that will be found highly profitable in connection with lead joints.

Any form of joint runner can be utilized, smearing it with wet clay before placing it around the pipe. The gate must be made larger than for lead and should be at least 6 to 8 inches high above the spigot. In the Metropolitan Water District work, clay is the material used for making gates in jointing pipe. In this connection, a round wooden gate peg is very useful. This peg is conical in form, 10 inches long, 2 inches in diameter at the bottom, and 3 inches at the top. The bottom of the peg is inserted between the ends of the joint runner where they come together to form the gate, then clay is built up about this peg, which is then turned around once or twice and withdrawn leaving a well formed gate of the right height.

The metalium gate buttons can be remelted, but it is important that they should be thoroughly cleansed and broken up before being put back in the melting pot.

From the foregoing, it is evident that the technique of this jointing material is simple, and it can be easily mastered by the ordinary workman; moreover, when faithfully carried out, it will afford highly satisfactory results. However, it should be remembered by those contemplating the use of metalium, that they will arouse the resentment of calkers, for the very good reason that the adoption of this material means their practical elimination. This was the experience in Omaha. Every calker at once insisted that metalium was a failure, and tried to make it a failure, even going so far as to throw dirt surreptitiously into the joints ready to pour. Failing in this, they sent their friends to the Water Board with warnings as to the dangerous innovation that was being attempted. All this, now, of course, is past and gone, so far as the Metropolitan Water District work is concerned, but others attempting to use this material will probably meet with the same experience, as human nature is the same the world over.

NEW DESIGN OF SCREEN CHAMBER[1]

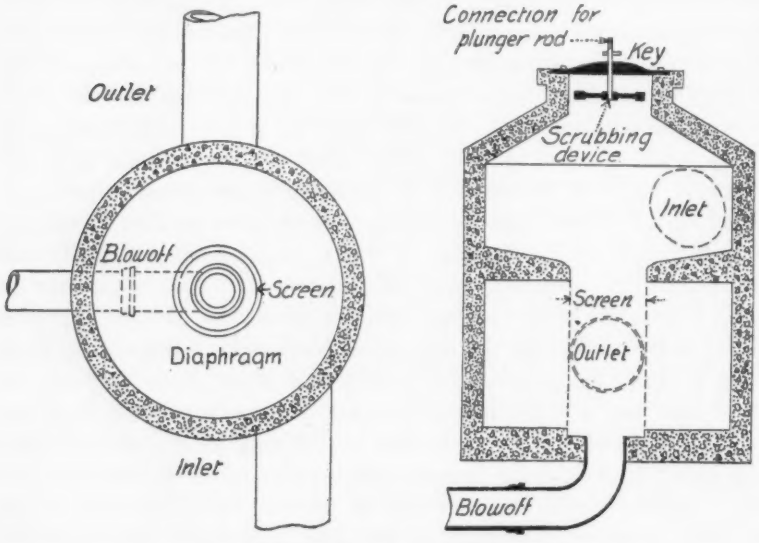
By John H. Lance

In the use of water for supply purposes, its freedom from foreign bodies is of prime importance. While ordinarily the water of driven or dug wells or infiltration galleries is free from detritus, all stream, reservoir and lake supplies require careful screening before the water is admitted to the distribution system. Among the bodies to be removed from the water are grass, leaves, sticks, bits of bark, and fish; and by far the most troublesome of these are leaves in all stream and small reservoir supplies. Masses of water grass only occasionally move to the point of intake; sticks usually only by reason of a high stage of water in the source of supply. Unlike these substances, which do not often of themselves form, by lodging against the screen, a tight barrier to the passage of water, leaves may practically seal the screen and effectually shut off the supply. This result may be caused also, but rarely, by small fish, of such a size as to be unable to resist being carried by the current at the intake. When they have been held against a screen for twenty-four hours, these fish make a tight seal and a very difficult coating to remove; one that is not readily released when the pressure is removed, as are leaves. Only the rarity of conditions favoring such occurrences spares the water-works operatives a vast amount of trouble. On the other hand, the leaf nuisance, especially in supplies from small reservoirs and streams, makes constant demands upon the attention of the operatives for a considerable part of the year.

The customary method of removing these substances is to install at the intake of the supply main, a screen affixed to the pipe, or two sets of screens in series, which may be drawn up out of the water for cleaning and replaced again for service. The former arrangement which is applicable only to very small depths of water on the screen, is economical in first cost, but its use has not always proved so economical; for owing to any one of many causes the screen might not receive the necessary attention at the very time when it was most needed. The latter arrangement necessitates a consider-

[1]Read before the Richmond Convention, May 9, 1917.

able structure to hold the screens in place and house them while being cleaned. If the reservoir is of great depth the process of cleaning is tedious and expensive, involving, as it does, the hauling up of all the screens in one set and their replacement, for each cleaning. During the time of cleaning the upstream set, the downstream set is receiving leaves and trash. While the cleaning of this set takes place, much of the débris lying against the screen, and any fish between the two sets, go down into the supply main to appear at the various fixtures of consumers or block the operation of meters.



A New Type of Screen Chamber

To obviate these difficulties the pressure screen-chamber here described was designed. It consists essentially, of a vertical cylinder divided by a horizontal diaphragm into two compartments. The upper or inlet compartment communicates with the lower or outlet through a circular opening in the diaphragm and thence through the meshes of an open-ended cylindrical screen resting in the lower compartment, of a diameter nearly that of the opening. The lower end of the screen is concentric with the end of a blow-off pipe with a gate valve on it, normally closed. The inlet pipe enters the inlet compartment tangentially, while the outlet may leave in any direction relative to that of the inlet, preferably in a radial position. Any

flow from the inlet pipe sets up a whirling motion in the water in the upper compartment. In passing through the screen cylinder, it has a circumferential as well as a downward motion, which, owing to the passage of water through the meshes of the screen, diminishes as the bottom of the screen is approached. The result of this is to confine, largely, the foreign matter carried by the water to a central cone the base and height of which are approximately those of the screen. The upturned end of the blow-off pipe being made of nearly as great a diameter as the screen, this results in an accumulation of débris directly in the pipe. When blocking of the screen has progressed to a point at which there is a noticeable loss of head at the screen, as measured preferably by a mercury U-tube or a differential gage, the blow-off gate is opened. The head in the blow-off pipe is then reducted to zero, or nearly so, the hydraulic gradient from the reservoir to the screen chamber is increased, and the high velocity established is transmitted directly to the water passing diagonally downward over the face of the screen and out the blow-off pipe. Ordinarily, the cleaning of the screen is accomplished in about the time that it takes to open and close the blow-off gate. If it is desired to maintain a considerable continuous flow through the outlet pipe, the blow-off gate need not be opened wide, in which case the operation will require a longer time. Under no conditions is an appreciable amount of water wasted.

Also incorporated in the design is a hollow segmental brush, for use in cases when the screen does not have attention for such long periods that a deposit of small fish is not readily removed by the flowing water.

For the intake pipes of pumping stations the devices are best set in batteries of two, so arranged that one can be put in service while the other is being cleaned. In this case the cleaning is preferably done by jets of high-pressure water directed downward from the edge of the diaphragm across the screen. Where electric power is available, the use of proper contact devices at the point of measurement of the loss of head at the screen will make the entire screening operation automatic, both for gravity and pumping supplies.

For use with a gravity water supply, the devices have been found to operate most successfully between the heads of 40 and 60 feet, though there is no valid objection to their use at other heads, under certain conditions. They are made entirely of reinforced concrete with the exception of the manhole cover, which is of cast iron.

The principle of pressure screening, from which the design was developed, was first suggested by O. M. Lance, General Manager of the Spring Brook Water Supply Company. The operation of the screen chambers has been found to be so economical and efficient that they have been adopted as a standard by the above named company. As convenient, all its supply lines, 20 in all, will be equipped with the new device, and the old sliding screens removed, only bar screens being left in place. The new screen chambers have been patented.

REMOVAL OF IRON, MANGANESE AND CARBON DIOXIDE FROM WATER[1]

ROBERT SPURR WESTON: There was a very interesting case of decarbonation at a plant which the speaker cannot refer to by name. The works were originally supplied from ground-water sources. Lead poisoning developed to an alarming degree, and as a result the ground-water supply was abandoned in great part and slow sand filters installed, taking a very highly colored ground water, purifying it to a very good degree and supplying it to the city. The ground water in the beginning contained 55 parts per million of carbonic acid. When the slow sand filters were started, of course the carbonic acid content of the water furnished to consumers was reduced to practically that of the surface water, less than 10 parts per million, and the corrosion of the lead pipe services stopped immediately. After a period of about fifteen years of operation of the sand filters much coagulated brown vegetable matter accumulated in the sand, and the filters were so efficient that they converted this brown vegetable matter into carbonic acid, so that three years ago the amount of carbonic acid in the sand filter effluent was nearly what it was in the well water some years before and, strange to say, the wife of the attorney of the water company developed a very severe case of lead poisoning, and the matter had to be attended to.

Experiments were made similar to those made by the author and the conclusion was reached that aeration alone increased the corrosive action of the water on the lead surfaces to a great degree, and that the carbonic acid which was left in the water after aeration was more corrosive than the original amount without the oxygen. It was found, however, that the addition of very small amounts of either lime or magnesium oxide, the latter particularly, would practically prevent the corrosive action on the lead. The amount added was about 8 parts per million of quicklime or 6 parts per million of magnesium oxide, equivalent to about one-half grain to the gallon.

[1] Discussion of a paper by Frank A. Barbour on "Decarbonation and Removal of Iron and Manganese from Ground waters at Lowell, Mass.," in the JOURNAL for June, 1917

This slight addition increased the hardness somewhat, but it was decided to apply the method. The addition of lime with aeration did not produce the best results. The water at that time contained over 1 part per million of lead and was treated with about 10 parts per million of lime.

This application was immediately followed by a reduction in the amount of lead and now, nearly at the end of the third year of operation, the lead in the water in ordinary use has been reduced to about 0.08 part per million; and in conditions where the water stands in services over night, to about 0.26 part per million; in both cases considerably less than the permissible amount. As to "permissible amount," the speaker believes that any lead at all in water is injurious, because the result is cumulative. The people noticed a slight increase in hardness after treatment, less than 35 parts per million but they have made no complaint. All danger of lead poisoning seems to have been averted forever. This method is used in England in treating certain waters that are acid, and the treatment with lime simply cures the acidity of the water due to carbonic acid or organic acid.

The method of removal of iron and manganese from water must be predicated upon the character of the water. Iron and manganese dissolved in water will nearly always precipitate out as iron or manganese rust. Practically all that we can do is to hurry the operation. Where the water is hard, as it is in some of the western states and in Germany, simple aeration and filtration is all that is required; in these cases it does not seem to make much difference whether you use slow filters or rapid or whether you use tricklers or not; but the removal of small amounts of iron from soft water is more difficult. Small amounts of iron in conjuction with manganese, or in conjunction with coloring matter, require more time than where the amounts of iron and manganese are large.

The most difficult water that the speaker has had to treat has been in his own house; the water has only 0.5 part per million of iron and considerable manganese, but a great deal of coloring matter. Another difficult case was the water supply at Cohasset, Mass., where a mechanical filter was first installed, which removed the iron perfectly and also the manganese without the use of coagulants. Within the last three or four months the color of the raw water, due to a near-lying peat bog, has increased so greatly that it has been necessary to add sulphate of aluminum to the water before passing it to the filter.

As to the choice of filters, the speaker believes that when a sand filter operating at a rate of 10,000,000 gallons per acre daily will do the work it will prove cheaper in practice, as a rule, than a mechanical filter at a rate of 125,000,000 gallons. Where the mechanical filter rate can be increased, where the head conditions are favorable, it may prove cheaper, and where the iron or manganese respond readily to treatment there is no reason why a mechanical filter should not be used where economic conditions favor it.

Recently, Dr. Corson prepared a paper in which he ascribes a great deal of the removal of manganese to the presence of a catalytic agent, that is, an agent which carries oxygen or effects the removal of the iron by catalysis. In Germany they have made similar experiments; they have, for instance, used shavings impregnated with tin oxide and various compounds supposed to be oxygen carriers, and passed these iron waters over them, with good results. However, it appears that other German investigators have shown that the same results can be obtained with sand filled filters. It has been shown that the film of iron or manganese hydrate on the surface of the sand will absorb oxygen, store it, and give it off. So the speaker is not yet in a position to accept the theory of catalysis, that it is the carrying of the oxygen by the oxide or the hydrated oxygen precipitated on the filter material which does the work; but rather that the iron and manganese which are readily oxidized are held in a fine collodial suspended condition and are absorbed by the film on the sand and held there until coagulation can take place, after which the film gradually increases in bulk until it sloughs off the trickler and is precipitated in the subsiding basin, or is removed from the surface of the sand filter.

At Middlesboro, in a plant somewhat similar in design to the author's but very much smaller, it was found that during the first year the manganese was reduced from about 0.56 to 0.15 part per million, but during the second year it was completely removed. The iron at Middlesboro has been reduced to an average of about 0.25 part per million.

During experiments at Brookline, contrary to the Lowell experience, it was found that the more contact of the water with air the better were the results that could be obtained. Again the speaker would say that what will work with one water will not work with another.

At Stargard, in Germany, where the iron and manganese are removed quite readily, the red discoloration or precipitation of iron

is observed in the upper few inches of the gravel filter. Below that there are about 6 inches of clean gravel where neither iron nor manganese is being removed. Below the clean layer is a black layer where the manganese has accumulated, and below that clean gravel again, showing that the manganese oxidizes much more slowly than iron and requires more time, more contact, more help. It is for this purpose that subsiding basins, coagulants, coke tricklers, etc., are used to treat soft colored manganiferous waters before filtration.

JOSEPH RACE: The speaker could corroborate the statements just made regarding the plumbo-solvency of the waters in the north of England. Almost all water derived from the uplands situated near the Pennine range was in this category and required treatment of some kind to rectify this condition. The generally accepted hypothesis in England was that the action on lead was due to the presence of humic and other organic acids and it had been found that the plumbo-solvency could be rectified by the addition of caustic lime or soda or carbonates of lime or soda. The experiments made by Heap at the Manchester University appeared to indicate that oxygen and not carbonic acid was the most potent factor in the solution of lead, but as these results were obtained with waters that are very different from that treated by the author the problems are not analogous.

EDWARD BARTOW: With respect to iron removal in Illinois, two methods are employed. One is used at Freeport, where lime is used to remove the iron, the other at Champaign, where aeration and filtration with mechanical filtration removed about 2 parts per million, giving very satisfactory results.

Recently the Illinois Water Survey was asked for advice concerning a proposed water supply for Johnson City in the coal mining district. The problem was to remove 95 parts per million of iron from water having 4200 parts residue. Compare that with the 2 parts per million of iron which it is necessary to remove at Lowell from a water having a residue of about 34 parts per million, less than 0.01 per cent of the amount in the Johnson City water supply. It was proposed to remove the iron by aeration and mechanical filtration. The resultant water could not be very satisfactory because the treated water would contain about 3000 parts per million of sodium sulphate, which would surely have a bad effect on those not accustomed to its use.

For manganese removal, the speaker has tried experimentally the zeolites and also aeration and filtration. The zeolites as used in Europe will remove manganese; but manganese dioxide itself, or manganese dioxide developed on the sand grains, was efficient. The manganese dioxide was developed on the sand either artificially by means of alkali and a manganese salt or by very slow accretion after the filter was put in operation. There are two plants in the state which are removing manganese by means of mechanical filters where the sand grains have been coated with the manganese dioxide.

It is interesting to note the change in operating at a plant near Berlin, Germany; formerly aeration over baffles followed by slow sand filtration was used, but in a new plant opened in 1914 aeration by spraying, followed by a mechanical filtration, is used.

SAMUEL B. APPLEBAUM: There are two questions the speaker desires to ask the author: First, in regard to the effect of increasing the amount of dissolved oxygen in the water upon aeration; has the author made any experiments as to the effect of aerated water on iron pipes in addition to his experiments on lead pipes, in order to ascertain the relative corrosiveness? He observed the interesting fact that the use of aeration was preferable to the use of an alkali to eliminate the corrosive effect of the water on lead. It would have been interesting if he had also tried experiments to ascertain whether the same effect, or the contrary, was true regarding the corrosiveness of the aerated water as compared with lime-treated water upon iron piping.

The second question is whether the author has made any experiments with the use of zeolites coated with higher oxides of manganese for the removal of iron and manganese in the Lowell supply? Abroad there are many municipal plants making use of these contact zeolites for the removal of iron and manganese from water. There are six or seven plants in operation today in Germany, notably those at Dresden, Glogau, and Wilhelmsburg, which are removing iron and manganese by this method. There is also one plant in England near Liverpool that is using these contact zeolites for the removal of iron and manganese followed by a sodium-zeolite plant for the removal of hardness. In this country there are two small municipal installations using this method, one at Helmetta, N. J., and the other at Weyanoke, Va., where the treated waters are free from iron and manganese, and are used for domestic purposes.

SOCIETY AFFAIRS

ILLINOIS SECTION

The Illinois Section held a meeting at Peoria on November 15, 1917, 47 members and guests being present. Visits were made to wells 7 and 8 and to the main pumping station of the Peoria water works where luncheon was served, and to the plants of the Avery Manufacturing Company, the Holt Manufacturing Company and the Keystone Steel & Wire Company. Dinner was served at the Creve Coeur Club, and at the meeting afterward H. B. Morgan described the Peoria water-works and read a paper on "The Deep Water Way," and C. B. Burdick read a paper on the "Water Works of Camp Grant."

NEW MEMBERS

Active

Jesse H. Wilson, City Engineer, Idaho Falls, Idaho.

Marion A. Jensen, Chief Engineer and Superintendent of Water Works, Nebraska City, Nebraska.

Federico Klein, Electrical Engineer, San Salvador.

Abel Wolman, Sanitary Engineer, Baltimore, Maryland.

Wm. J. Leach, Superintendent and Chief Engineer, Fergus Falls, Minnesota.

J. Mitchell Heffelfinger, Engineer, Illinois State Water Survey, Urbana, Illinois.

Frank E. Howard, President Water Board, Hartford, Connecticut.

Fred. D. Berry, Secretary, Water Board, Hartford, Connecticut.

C. M. Saville, Manager and Chief Engineer Water Board, Hartford, Connecticut.

Clarence F. Ames, Superintendent Water Works, Norwich, New York.

Charles Rapelge Wyckoff, 150 Nassau Street, New York, New York.

Richard W. Sherman, 104 South Lake Avenue, Albany, New York.

James A. Shepard, Bisbee-Naco Water Company, Bisbee, Arizona.
A. D. Leerskov, Superintendent Water Works, Brush, Colorado.
Vratislav Adolph Zehr, Mechanical Engineer, Quincy, Illinois.
Warren G. West, Superintendent and Secretary, Water Company, Leadville, Colorado.
Cornelius M. Daily, Engineer in Charge Supply and Purification Department, St. Louis.
Dale L. Maffitt, Chemist and Bacteriologist, Des Moines Water Company, Des Moines, Iowa.

Corporate

Manhasset-Lakewood Water District, Manhasset, New York.
Citizens Light, Heat and Power Company, Tracy, Minnesota.

OBITUARY

D. C. Crandall, Tupper Lake, New York, December 19, 1917.
Albert Blauvelt, Chicago, Illinois, January, 1918.
Howard E. Ahrens, Reading, Pennsylvania, February 26, 1918.
Harry A. Lord, Ogdensburg, New York, March 11, 1918.

ROLL OF HONOR

Following are additional names to the Roll of Honor printed in the March JOURNAL:

ATKINSON, MYRON H. (son T. R. Atkinson), O.T.C., Camp Devens, Massachusetts.

BAKER, FREDERICK W. (son M. N. Baker), O.T.C., Camp Upton, New York.

CLAIBORNE, HERBERT A., Lieutenant Signal Reserve Corps, Aviation Concentration Camp, Morrison, Virginia.

FALLER, C. P. (son C. Faller), Lieutenant 11th Infantry, Camp Forrest, Georgia.

HYMMAN, GORDON (son H. Hymman), Sergeant Co. A, Royal Canadian Infantry, Military Convalescent Home, Guelph, Ontario.

KILPATRICK, JOHN DOUGLAS, Lieutenant Colonel Quartermaster Corps, Constructing Quartermaster, Camp Wadsworth, Spartanburg, South Carolina.

LONGLEY, FREDERICK J., Lieutenant Aviation Section, Signal Corps, 271st Aero Squad, Ellington Field, Houston, Texas.

MALLALIEU, WILLARD C., Sanitary Corps, N.A., Camp Greenleaf, Georgia.

LETTON, H. P., Captain Engineers, N.S.R.

MOHLER, BRUCE M., 1st Lieutenant Sanitary Corps, N.A., Army Medical School, Washington, D. C.

RANDALL, W. T. (son W. H. Randall), Signaller 108th Battalion (Canada), B.E.F., France.

WILCOX, WILLIAM F., JR. (son W. F. Wilcox), Sergeant 106th Supply Train, 31st Division.

WOOD, EDWARD R., JR., Captain 18th Field Artillery N.A.